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# 1981 AGU Fall Meeting

San Francisco
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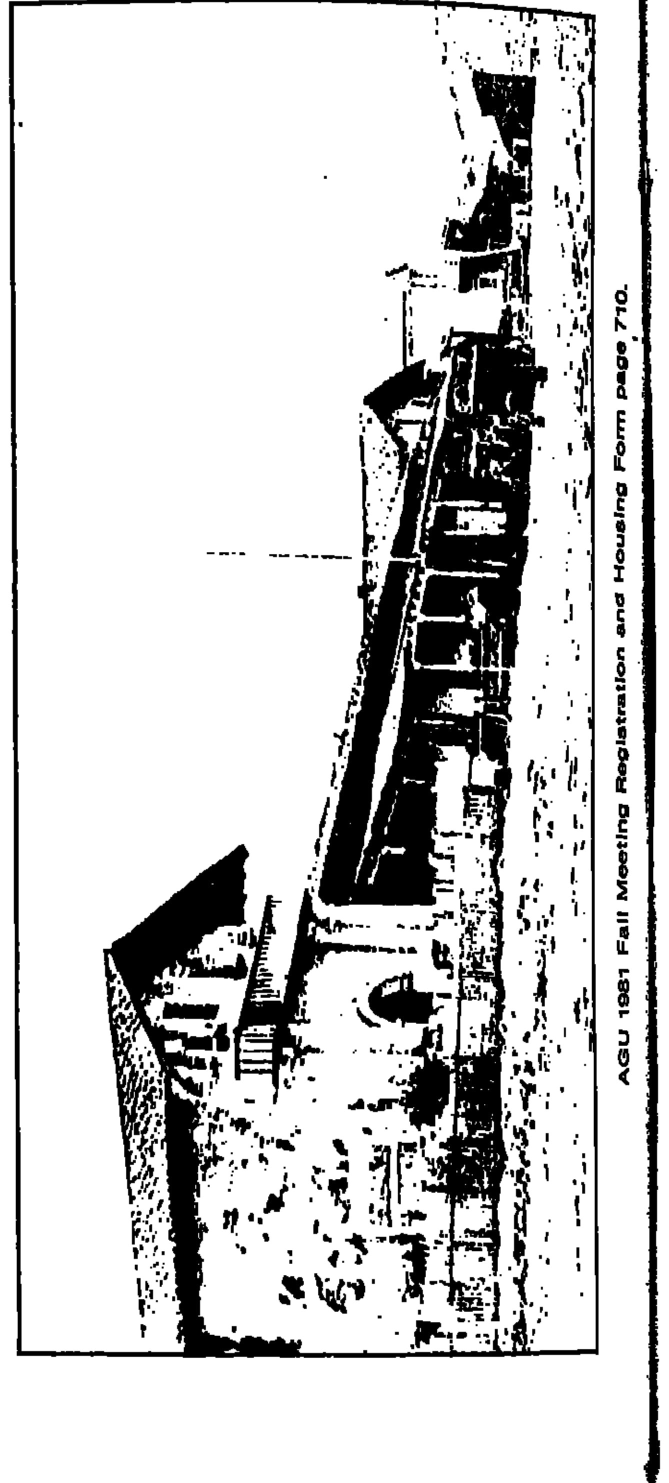

AGU 1981 Fall Meeting Registration and Housing Form page 710.

EOS, TRANSACTIONS, AMERICAN GEOPHYSICAL UNION VOL. 62, NO. 42, PAGES 705-712 OCTOBER 20, 1981

## Physical Properties of Rocks

6140 Magnetic and electrical properties
INVESTIGATION OF INDUCED MAGNETIZATION VARIATIONS CAUSED BY TRIAXIAL STRESSES
J.Zlotnicki (Institut de Physique du Globe, 4, Place Jussieu, 75230 Paris Cedex 05, France), J.P.Pozzi and F.H.Cornet.

Laboratory experiments have been conducted to investigate the change in induced magnetization caused by triaxial stress variations on andesite specimens. Induced axial magnetization was found to decrease with the increment of axial load (as is the case for uniaxial stress conditions), for a constant confining pressure, whilst induced radial magnetization increased with axial load increments. This relationship between stress changes and induced magnetization variation was found to depend on the confining pressure magnitude and the maximum axial stress previously reached : the larger the confining pressure, the larger the effect on induced axial magnetization, but the smaller the effect on induced radial magnetization ; the larger the maximum differential stress the smaller the effect of stress variation on both axial and radial induced magnetization except for uniaxial stress condition. For small maximum differential stresses or maximum axial stress conditions close to the maximum load bearing capacity of the material, this relationship was found to be linear so that a tensorial formulation could be proposed for small magnetic fields. This led to the definition of a fourth order tensor which is called the piezomagnetic tensor. The important geophysical implications of these results are that the influence of deviatoric stress variations on induced magnetization increases with depth, provided the maximum differential stress supported in the past by the material is not close to that necessary for failure to occur ; for this last instance the influence of a pure deviatoric stress variation is independent of the spherical component of the stress state. Accordingly pore pressure variations could generate induced magnetization variations for those rocks which have not been loaded close to failure. (Induced magnetization, triaxial stress).
J. Geophys. Res., Red, Paper 1B1335

[illegible] techniques (fluid transport)
DESIGN CRITERIA FOR LABORATORY MEASUREMENTS OF LOW PERMEABILITY ROCKS
[illegible] Trimmer (Lawrence Livermore National Laboratory, P.O. Box [illegible], Livermore, California [illegible])

The advantages and limitations of two versions of the pulse technique for laboratory measurements of low permeabilities ($10^{-15}$ to $10^{-24}$ m²) are discussed. The transient pulse technique developed by Brace et al. [1968] is the preferred method because of the ease of data reduction. The modified transient pulse technique developed by Trimmer et al. [1980] can be used when the assumptions inherent in the transient pulse technique are invalid.

The systematic error associated with the transient pulse technique is a function of the ratio of the effective sample pore volume to the reservoir volumes. If this ratio is less than 0.25, then the error associated with the transient technique is less than 10%. The modified transient pulse technique does not suffer from this systematic error. Criteria are also presented for optimizing the experimental configuration for measurement durations as well as ease of data reduction. (Permeability, Transport, Hydraulic Conductivity).
Geophys. Res. Lett., Paper 1L1212

6199 General or miscellaneous
IMPLICATIONS OF THE MECHANICAL AND FRICTIONAL BEHAVIOR OF SERPENTINITE TO SEISMOGENIC FAULTING
Carlos A. Dengo and John M. Logan (Center for Tectonophysics, Texas A&M University, College Station, TX, 77843)

The widespread occurrence of serpentinite along major strike-slip, seismogenic faults warrants systematic investigation to determine how its frictional characteristics may affect slip along the fault. Different locations along the Motagua fault zone in Guatemala were sampled to investigate the sliding mode as a function of composition and texture, confining pressure, and displacement rate. Air dried, right circular cylinders, 7.1 cm in length and 3.3 cm in diameter, with a precut 35° to the cylinder and load axes were deformed at confining pressures up to 200 MPa, room temperature, and displacement rates of $10^{-4}$ cm/sec and $10^{-7}$ cm/sec. Compositional analyses of specimens cored from five blocks of serpentinite that were tested show that the serpentinite can be divided into two groups. One is a mesh-textured serpentinite containing up to 70% serpentinite, mostly lizardite, 11% enstatite phenocrysts, 19% oxides, and minor amounts of olivine and carbonate (undifferentiated). The other is a flare-textured serpentinite containing up to 84% serpentine, mostly antigorite, 10% oxides, 6% magnesite and dolomite, and almost no enstatite or olivine. The flare-serpentinite undergoes the transition from stable sliding to stick-slip sliding at confining pressures as low as 10 MPa. The mesh-serpentinite results only in stable sliding up to confining pressures to 200 MPa and a displacement rate of $10^{-4}$ cm/sec. At a displacement rate of $10^{-7}$ cm/sec only one of the three mesh blocks exhibits stick-slip.

The shear stress required to initiate sliding for the flare-textured serpentinites is given by $\tau = 0.77\sigma_n$. For the mesh-textured serpentinites at a displacement rate of $10^{-4}$ cm/sec it is given by $\tau = 0.56\sigma_n$, and at a displacement rate of $10^{-7}$ cm/sec by $\tau = 0.60\sigma_n$. Differences in fracture strength between the five specimen-blocks correlates with differences in frictional strength.

Differences in the sliding behavior and in the deformation observed along the sliding surfaces can be related to the mineralogical components of each serpentinite type. Extensive deformation occurs in the mesh-serpentinites as a result of hard oxide and enstatite indenters ploughing through a soft lizardite substrate. Lizardite-lizardite contacts prevail and these deform by plastic flow. The stick-slip behavior in the flare-textured serpentinites is explained by brittle failure of antigorite-antigorite contacts. The smaller grain size of the flare-serpentinites relative to the mesh-serpentinites, may also contribute to the higher frictional strength of the flare-serpentinites.

We discuss the implications of the antigorite-rich, flare-textured serpentinite to seismogenic faulting. In particular, we consider the case of antigorite forming by shear-heating-induced progressive metamorphism of lizardite-chrysotile serpentinites. If serpentine dehydration temperatures are approached talc may form. Having a lower coefficient of friction than serpentine, talc may act as a "lubricant" along the fault plane.
J. Geophys. Res., Red, Paper 1B1100

## Planetology

6510 Atmospheres of planets
THE IONOSPHERIC PEAK ON THE VENUS DAYSIDE
T. E. Cravens (Space Physics Research Laboratory, Department of Atmospheric and Oceanic Science, The University of Michigan, Ann Arbor, Michigan 48109), A. J. Kliore, J. U. Kozyra, and A.F. Nagy

Many electron density profiles of the dayside ionosphere of Venus have been measured by the Pioneer Venus Orbiter between December, 1978 and October, 1980, using the dual-frequency radio occultation technique. The peak electron density as a function of solar zenith angle can be describedby a simple Chapman layer theory with proper normalization; however, it does not predict adequately the height variation of the electron density peak. In order to interpret these radio occultation results, we have constructed a theoretical model describing the ion composition and electron density in the vicinity of the ionospheric peak. Good agreement between the model and the measurements was obtained only with a specific choice of the neutral densities, the electron temperature, and the level of solar activity.
J. Geophys. Res., Blue, Paper 1A1361

6575 Surface of planets
STABILITY OF GOETHITE (α-FeOOH) AND LEPIDOCROCITE (γ-FeOOH) TO DEHYDRATION BY UV RADIATION: IMPLICATIONS FOR THEIR OCCURRENCE ON THE MARTIAN SURFACE
Richard V. Morris (Code SN7, Geochemistry Branch, NASA Johnson Space Center, Houston, TX 77058) and H. V. Lauer, Jr.

The stability of submicron powders of goethite (α-FeOOH) and lepidocrocite (γ-FeOOH) to dehydration by ultraviolet (UV) radiation was investigated by laboratory experiments. Dehydration of these minerals by solar UV radiation is potentially an important process on the surface of Mars. When the spectral irradiance of the incident radiation was about 100 to 300 times that of the solar spectral irradiance at 1.5 AU (the orbit of Mars), radiant heating was so intense that both FeOOH polymorphs were thermally dehydrated. When the above incident radiation was optically filtered to remove a large portion of the infrared and visible components, but not the intense near-UV component, no perceptible dehydration, and therefore no UV photodehydration, was observed after irradiation times as long as 420 hours. After scaling the laboratory irradiance to that at the Martian surface, we calculate that goethite, lepidocrocite, and presumably all FeOOH polymorphs would not perceptibly UV photodehydrate there for at least 10 to 100 years. That is, there is as yet no basis in laboratory experiments for inferring that UV photodehydration of FeOOH polymorphs will occur naturally on the surface of Mars on a time scale of 10 to 100 years, if at all. Thus, the observation that goethite may contribute to the spectral reflectance data on Mars (e.g., Singer et al., 1979) is consonant with our results. The formation of maghemite ($\gamma$-$Fe_2O_3$) by UV photodehydration of lepidocrocite does not seem a viable mechanism for producing the former to account for the magnetic component apparently present in Martian surficial material (Fuller and Hargraves, 1978; Hargraves et al., 1979). Finally, ferrimagnetic δ-FeOOH remains a viable candidate (Burns, 1980) for the magnetic material with respect to FeOOH stability to UV photodehydration. (Mars, goethite, lepidocrocite, weathering).
J. Geophys. Res., Red, Paper 1B1271



# Editorial

## The AGU Budget

The process of developing a budget for AGU is long and complicated. It begins fairly early in a calendar year, when results of the prior year's accounts are fairly well known. Thus the 1982 budget process began early in 1981. Budgets are presented to the Council in preliminary form at the Spring Meeting and in final form, for approval, at the Fall Meeting.

The finances of the Union are generally in very good shape, but the total liquid assets are very small for a scientific society of our size. Therefore the Council decided some time ago that the assets should be built up in two ways. The first was a fund-raising campaign, about which all members have been contacted. The goal for this fund-raising campaign is $1,000,000 during the next 5 years. The second was to raise out of operations a similar amount during the next 5 years. This means that the bottom lines for the operating part of the budget should add up to $1 million during the next 5 years (1981–1985). This will be unevenly distributed such that this year we hope to achieve a net surplus of $100K, rising evenly to a surplus of $300K in 1985. It is the business of the Budget and Finance Committee, with advice from other committees (such as the Publications Committee) and with primary inputs from the AGU staff, to arrive at a budget that achieves these modest balances, which are about 4% of the total operating budget, during each of the next 5 years.

The Budget and Finance Committee finds it useful to divide the activities of the Union into those projects that generate income and those that do not. Examples of the former are things like meetings, books, and journals, whereas the latter include the money spent in support of the Congressional Science Fellow program, scholarships, membership directories, and the public information program.

As a rational basis for development of the budget, the Budget and Finance Committee and the general secretary have suggested that each of the income-generating programs should aim for the contribution of an equal percentage to the operating surplus of AGU. This statement needs some clarification, which we shall do by using an example. In the budget for 1981, which is shown in the accompanying inset, the projected cost of producing the *Journal of Geophysical Research* is $1379K. As shown in the detailed summary for JGR, this sum of money includes all anticipated charges that can be directly identified with JGR, such as editors, honoraria, office costs, copy editors' salaries, typesetting, printing, and mailing. In addition, the general and administrative costs at the AGU headquarters—which include such overhead items as building occupancy, the personnel department, and accounting—must be apportioned out to all of the activities within AGU if a true total cost picture is to be obtained. These general and administrative costs make up the administration and finance divisions and the executive director's office. They are apportioned out in proportion to the salaries related to each project. JGR's share for 1981 is $161K.

Finally, there are other costs within the AGU Publications Division that cannot easily be assigned directly to any individual project. This divisional overhead, loaded with its own share of the general and administrative costs, is apportioned out to each project within the publications division in proportion to the direct costs of each project. Since JGR has 38.9% of the direct costs within the publications divi-

(cont. on page 714)

American Geophysical Union 1981 Budget for Operations Income and Expense by Activity (× $1000)

| | Income | Expense |
|---|---|---|
| *Publications Division* | | |
| Journal of Geophysical Research | 2101 | 1379 |
| Eos | 356 | 330 |
| Water Resources Research | 419 | 263 |
| Reviews of Geophysics & Space Physics | 221 | 144 |
| Geophysical Research Letters | 236 | 192 |
| Radio Science | 189 | 142 |
| Russian Translations | 678 | 540 |
| Books | 469 | 448 |
| Chinese Geophysics Series | 35 | 33 |
| Subsidiary Publications | 70 | 66 |
| Other Publications Services | 14 | 10 |
| Publications Division Overhead | — | 382 |
| Total Publications Division | 4788 | 3929 |
| *Member Programs Division* | | |
| Member/Customer Services | 113 | 29 |
| Spring Meeting | 124 | 74 |
| Fall Meeting | 119 | 67 |
| Other Meetings | 29 | 26 |
| Public Affairs | — | 39 |
| Education & Human Resources | 2 | 14 |
| Awards | — | 3 |
| Associated Societies | 66 | 55 |
| Other Member Programs Activities | 58 | 53 |
| Member Programs Division Overhead | — | 80 |
| Total Member Programs Division | 511 | 440 |
| *Miscellaneous Projects* | 6 | 9 |
| *General and Administrative* | | |
| Administrative Division | — | 482 |
| Finance Division | 50 | 170 |
| Executive Office | — | 213 |
| Total General and Administrative | 50 | 865 |
| TOTAL OPERATIONS | 5355 | 5243 |

# Kimberlites: Strange Bodies?

Jill Dill Pasteris

*Department of Earth and Planetary Sciences and McDonnell Center for Space Sciences*

### Introduction

Several years ago I asked a well-known mantle petrologist why kimberlites had been studied relatively little in comparison with kimberlite-transported xenoliths from the upper mantle and lower crust. He replied, 'When I see a bus full of people travel by, I'm more interested in the passengers than in the bus.' For many years kimberlites were relegated to the status of the vehicle for a petrologically intriguing load of xenoliths.

There are several reasons for the initial lack of attention to kimberlites. (1) They are highly brecciated and inclusion-rich. Many petrologists viewed them as a confusing potpourri of exogenous and endogenous fragments. In fact, some were uncertain whether kimberlites had any primary magmatic/liquid component. (2) Kimberlites usually have undergone a high degree of alteration, principally serpentinization and carbonation, but in some cases localized phlogopitization. Initially, most of the alteration was viewed as very late-stage, probably post-magmatic, and some of it perhaps due to weathering. (3) Because of their brecciated, altered condition, kimberlites often are porous, friable, and difficult to make into thin sections.

All of the above features and perceptions made kimberlites seem unamenable to modern petrologic analysis and difficult to interpret. The former statement I hope to show is untrue; the latter is true, but should serve to encourage further petrologic investigation.

In addition to their association with mantle xenoliths, kimberlites have another strong redeeming feature: They are the rocks in which diamonds are found. The question remains whether kimberlites are the source of the diamonds or again merely the vehicle of their transport [e.g., *Boyd and Finnerty*, 1980]. Researchers at the De Beers Geology Department and at the Anglo American Laboratories in South Africa have spent years studying and classifying a large number of kimberlite types. On several occasions, kimberlite researchers and other mantle petrologists have come together at international conferences, some of which have given rise to special volumes in the literature: First International Kimberlite Conference, 1973, in South Africa (see *Phys. Chem. Earth, 9*, 1975); Second International Kimberlite Conference, 1977, in Santa Fe, New Mexico [see *Boyd and Meyer*, 1979*a*, *b*]; Cambridge Kimberlite Symposium I (1975) and II (1979) in England. The Third International Kimberlite Conference is scheduled for September, 1982, in France. In addition, there was an entire talk session at the May 1981 AGU Spring Meeting devoted to 'Kimberlites and Other Strange Bodies.' Several other review volumes and compendia on kimberlites and their xenoliths are listed in the bibliography.

### What Are Kimberlites?

It has been difficult over the years to get petrologists even to agree on a definition of kimberlites, let alone to agree on their origin [e.g., *Dawson*, 1967*a*]. *Clement et al.* [1977] have provided a very useful definition, avoiding both genetic connotations and excessive petrologic restrictions:

> Kimberlite is a volatile-rich, potassic, ultrabasic, igneous rock which has a distinctly inequigranular texture resulting from the presence of macrocrysts set in an essentially microporphyritic matrix. The matrix contains as prominent primary phenocrystal and/or groundmass constituents, olivine and several of the following minerals: phlogopite, calcite, serpentine, diopside, monticellite, apatite, spinels, perovskite, and ilmenite. Other primary minerals may be present in accessory amounts. The macrocrysts belong almost exclusively to a suite of anhedral, cryptogenic ferromagnesian minerals which include olivine, phlogopite, picroilmenite, magnesian garnet, chromian diopside and enstatite. Olivine is extremely abundant relative to the other minerals which need not all be present. In addition to macrocrysts smaller grains belonging to the same suite also occur.

*Clement et al.* [1977] have used the nongenetic term 'macrocryst' for grains visible to the naked eye. The term cryptogenic is used when the origin is uncertain; that is, the macrocrysts could be either phenocrysts (precipitated from kimberlite melt) or xenocrysts (foreign grains).

In summary, kimberlite is characterized by its inequigranular texture (often porphyritic) and its mineral components, dominated by olivine (Figure 1). In many cases there are both first generation (large) and second generation (groundmass) grains of olivine and phlogopite. The effects of carbonation and serpentinization are characteristic. In addition, one frequently observes late-stage 'pools' of calcite ± serpentine in the groundmass. Macrocrystal pyrope-rich garnet and picroilmenite grains (most from mantle xenoliths) are often abundant (indeed, their presence is used as a prospecting tool in locating kimberlites). On a finer scale, the textures and chemistry of groundmass spinels and ilmenites also characterize kimberlite (Figure 2). In many cases, reaction relationships between early crystals and the kimberlite melt are prominent.

Elemental abundances in kimberlites are distinctive and have been investigated closely as a means of determining the origin of the initial melts [e.g., *Dawson*, 1967*b*, 1980]. Kimberlites are undersaturated rocks with a silica content usually near or below 33 wt %. Their alumina and titania contents are high for ultramafic rocks, whereas total iron is about average (~ 9 wt % calculated as total FeO). Compared to other ultramafic suites, kimberlites have a high alkali content (often greater than 1.5 wt % $Na_2O + K_2O$), the other hallmark being a K/Na ratio exceeding 3. Kimberlites are also volatile-rich; $H_2O$ often exceeds 7.5 wt %, and $CO_2$ is high (≥ 3 wt %) and variable. The large $P_2O_5$ content (0.5–1.0 wt %) is similar to that of granites.

Kimberlites occur in diatremes/pipes, sills, and dikes (see cover, this issue). It appears that many diatremes narrow and become dikes at depth [*Dawson*, 1967*a*]. The term 'blow' refers to the sudden expansion of a portion of a kimberlite dike into a pipe. Unlike diatremes, however, blows did not reach the surface during intrusion, but represent dead-end pipes [*Dawson*, 1980]. Most kimberlite diatremes record multiple intrusive episodes; that is, even on a macroscopic scale, one can identify more than one kimberlite facies. The mutually intruding rock types are often distinguished in hand specimen by color, friability, degree of alteration, and abundance of crustal and mantle xenoliths.

In general, it appears that kimberlites are primarily confined to stable cratonic regions (e.g., southern and western

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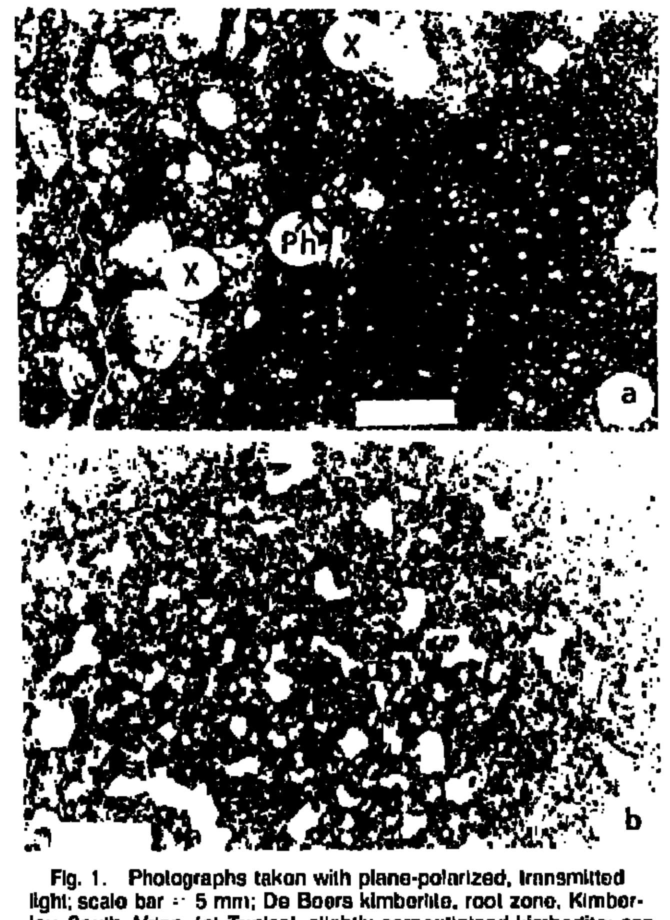


Fig. 1. Photographs taken with plane-polarized, transmitted light; scale bar = 5 mm; De Beers kimberlite, root zone, Kimberley, South Africa. (*a*) Typical, slightly serpentinized kimberlite; contact between coarse- and fine-grained material. Smaller, kimberlitic olivines (colorless grains) are euhedral. Many xenocrystic olivines (X), some of which are mosaic. Phlogopite (Ph) also common. Very fine-grained, dense crystalline groundmass appears black. (*b*) Kimberlite dike: kimberlite groundmass with irregular pools or segregations (white to gray) of calcite and what appears to have been a glass (now partly serpentinized).

( Budget cont. from page 713)

sion, it has charged to it 38.9% of the loaded publications division overhead, or $224K. Therefore, the total cost of publishing JGR is $1764K, which leaves an excess of income over expense of $337K or 20% of total costs.

In order to cover the costs of the Union's non-income producing projects and to build the surplus at the proposed rate over the next 5 years, it is necessary that the income from the JGR and other income-generating projects exceed the total direct and indirect costs. The target is to have all income-producing projects generate a percentage of surplus in the 10–20% range, which is what JGR and the annual meetings have been able to achieve historically. In some cases this cannot be achieved immediately. For instance, the new journal, *Tectonics*, will almost certainly not achieve this during its first years of publication, as it will take some time for the subscription level to build up. Other projects may never reach the target because of weaker markets and resulting highly elastic demand. Nevertheless, the percentage surplus figure does give each project a target to aim at, and it does give the staff and the various AGU committees a measure of how each project is doing.

*Journal of Geophysical Research*
Detail of 1981 Income and Expense Budget

| | | |
|---|---|---|
| *Income* | | |
| Individual subscriptions | 178 | |
| Institutional subscriptions | 1069 | |
| Page charges | 787 | |
| Reprints | 67 | |
| TOTAL INCOME | | 2101 |
| *Direct Expense* | | |
| Salaries | 160 | |
| Editorial offices | 164 | |
| Printing and mailing | 826 | |
| Reprints | 83 | |
| Postage | 91 | |
| Travel | 6 | |
| Data processing | 3 | |
| Direct cost allocations | 44 | |
| Miscellaneous | 2 | |
| Total direct expense | | 1379 |
| *General and Administrative Expense* | | |
| @ 100.6% of direct salaries | | 161 |
| *Publications Division Overhead* | | |
| Directly charged division overhead | 149 | |
| General and administrative allocation | 75 | |
| Total Publication Division Overhead | | 224 |
| TOTAL EXPENSE | | 1764 |
| NET INCOME | | 337 |

American Geophysical Union 1981 Budget for Operations Income and Expense by Category (× $1000)

| | |
|---|---|
| *Income* | |
| Dues | 236 |
| Individual subscriptions | 320 |
| Institutional subscriptions | 2442 |
| Page charges | 1219 |
| Reprints | 142 |
| Author alterations | 15 |
| Book sales | 383 |
| Back issues | 67 |
| Registration | 228 |
| Function fees | 4 |
| Grants and contracts | 162 |
| Miscellaneous | 21 |
| Advertising | 60 |
| Investment | 56 |
| TOTAL INCOME | 5355 |
| *Expense* | |
| Salaries | 1363 |
| Other personnel costs | 81 |
| Editor costs | 303 |
| Translation and edit | 165 |
| Printing and mailing | 2066 |
| Data processing | 99 |
| Audio visual | 25 |
| Facilities, food, and beverage | 44 |
| Services and supplies | 280 |
| Reprint expense | 167 |
| License fees/royalties | 78 |
| Telecommunications | 41 |
| Postage | 45 |
| Travel and official | 108 |
| Equipment costs | 43 |
| Depreciation | 19 |
| Rent | 180 |
| Insurance | 8 |
| Professional services | 69 |
| Grants and contributions | 86 |
| Miscellaneous expense | 38 |
| Cost allocations | (25) |
| TOTAL COSTS | 5243 |
| Net of income over Expense | 112 |

We now know what the income from any project should be. But in most cases there are different ways of achieving the same income. For instance, journals generate income from page charges, member subscriptions, and library (nonmember) subscriptions. The relative mix of income generated from these three sources is the subject of continuing debate. There is some feeling that member subscriptions should be kept relatively low and that page charges should be increased. This is because there appears to be an ever-growing number of high-quality papers submitted to our major journal (JGR), but at the same time the number of member subscriptions is declining. (The basic idea is to place the charge where the demand is high and least price-sensitive). Additional ideas are also considered in deciding how to generate the income. For instance, subscriptions should be based, in part, on the projected size of the journal. This idea is used to determine the relative member subscription rates to the different sections of JGR but has not been so widely used in determining the relative subscription rates between JGR and, for instance, GRL. It is also thought that the library subscription should be some fairly constant multiple of the member subscription.

One journal which is a consistent exception to these rules is WRR. This is because the Hydrology Section decided some time ago to raise the subscription rate so that the page charge collection percentage could be decreased. Thus, although the page charge for papers published in WRR is the same as that for JGR, the collection rate is only about 50% in the former, and well above 85% in the latter.

In other cases there is little problem about deciding where the money is to come from. For instance, the books program rarely has page charge income. The primary variable is the number to be sold at each discount rate. Thus the total expense of publishing the book (including the relevant overhead amounts and desired surplus) divided by the expected number of sales gives the average price of the book. The meetings program is also fairly simple in that the primary source of income is registration fees, which must therefore be set to cover direct and indirect expenses plus the normal surplus.

There are several things that can affect the ability of AGU to achieve its budget for any calendar year. For instance, the registration fee is based on a projected number of registrants at each meeting, which is done by the AGU staff on the basis of historical analyses of past meetings. Greater or smaller numbers of registrants will produce a larger or smaller surplus for this activity and so have an effect on the bottom line at the end of the calendar year. This effect is quite small, being only $5K for a deviation of 100 registrants with a registration fee of $50. A somewhat larger effect can be produced by varying journal size. Since the subscription rates for any journal are based on the projected size of the journal but the expenses are to some extent dependent on the actual size of the journal, any deviation between the projected and actual size can have a positive or negative effect on the bottom line. As an example, we suppose that JGR publishes 1000 pages more than the budgeted size during a year. This will cost about $150K extra to produce. This is offset in part by an increase in page charge collection that could amount to $90K, based on an 85% collection rate and a page charge of $105/page. Rather than require editors to live within the page budgets, it has been decided that subscriptions should be based partly on the projected size of the journal and partly on deviations between projected and actual sizes over the past year or so. Thus if a journal is greatly above or below its projected size, this next year's subscription will be (respectively) larger or smaller than normal.

One of the major problems with journals is that for reasons of publicity it is necessary to fix the subscription rates of journals in the middle of the prior year, when only about 25% of the papers to be published during the year will have been submitted. Therefore, a very important job which has to be done by the AGU Publications Division, aided by input from the various editors, is to arrive at their best estimate for the size of each journal.

Finally, it should be noted that the general secretary has the responsibility for determining subscription rates and other charges such as meeting registrations. Advice is given to the general secretary by the Budget and Finance Committee, the Publications Committee, and the AGU Council, in addition to the recommendations from the AGU staff. The general secretary attends all Budget and Finance Committee meetings and visits the AGU headquarters on a regular basis. One task of the general secretary is to monitor the finances of the Union operation throughout the year in order to determine if there are any gross departures from the established budget and to consult with the Budget and Finance Committee about such departures.

If you have any queries about the budget of AGU or about any other financial matters, please write to me c/o American Geophysical Union, 2000 Florida Avenue, N.W., Washington, D.C. 20009.

C. G. A. Harrison, *Chairman*
*Budget & Finance Committee*



(Kimberlites cont. from page 713)

Africa, Canada, United States, Brazil, Siberia, India), perhaps a function of the relationship between the geothermal gradient and the peridotite melting curve. Excellent reviews of the geographic and geologic settings of kimberlites are found in *Meyer* [1976] (for the United States) and in *Dawson* [1980] (worldwide occurrences).

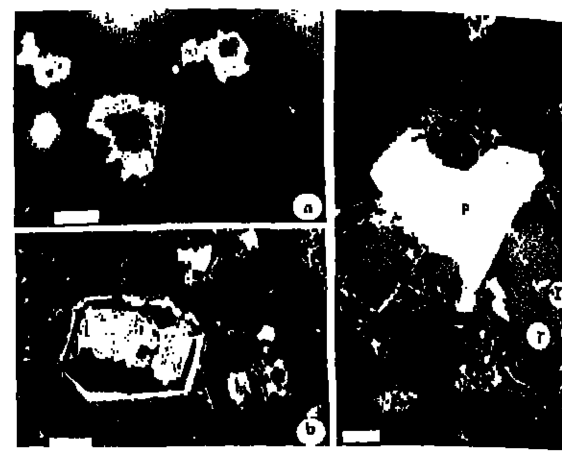

Fig. 2. Photographs taken with plane-polarized, reflected light, oil immersion objectives. (*a*) Spinel grains showing compositional zones, more Cr-rich at core and more Fe-rich and Ti-rich at edges. Nqechane kimberlite, Lesotho. Scale bar = 20 μm. (*b*) Compositional zoning in spinel showing atoll texture: core spinel, 'gap,' magnetite-rich rim. The gap here probably represents selective resorption of an earlier spinel zone. De Beers kimberlite. Scale bar = 20 μm. (*c*) Atoll spinels attached to perovskite (large white grain; P). Large spinel on right is zoned: chromite core, partly enclosed by crescent of ilmenite (light gray; I), fully enclosed in titanomagnetite (darker gray, T). Typical association in De Beers kimberlite. Scale bar = 10 μm.

What are kimberlites not? For several years there has been a controversy over the possible relationship between kimberlites and carbonatites [see *Mitchell*, 1979*b*]. The following similarities between the two rock types had been observed or postulated: both are undersaturated rocks; both contain mineral assemblages characterized by their high content of rare earths and other trace elements; both occur with alkalic ultramafic central ring complexes (according to *Mitchell* [1979*b*] this is a misconception); kimberlites frequently contain magmatic carbonate-rich segregations. However, a closer look at the respective mineral compositions of the two rock types and their different tectonic settings—rift areas for carbonatites and stable cratons for kimberlites—shows them to be distinctive entities. As discussed in a later section, both ultimately may have been derived from the same mantle parent, but they are derived by different degrees of partial melting and at different depths.


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**Cover.** Configuration of the De Beers kimberlite pipe, Kimberley, South Africa. Part A: Vertical section showing the three major depth zones in kimberlite pipes. At depth the pipe is a series of 'roots' as also indicated in parts C and D. Part B: Plan section enlargement of the east pipe shown in part D. Three major kimberlite facies are recognized in hand specimen and thin section. They probably represent two separate intrusions. Parts C and D: Plan sections showing change in pipe configuration with depth. Parts A and B are not to scale. Data courtesy of De Beers Consolidated Mines. (See article p. 713.)



## What Is the Origin of Kimberlites?

One of the most important and still unanswered questions concerns the mechanism of kimberlite melt generation. The major end-member hypotheses are (1) partial melting of mantle peridotite [e.g., *Dawson*, 1971; *Wyllie*, 1979*a*, *b*; *Eggler and Wendlandt*, 1979] and (2) fractional crystallization, or the 'residual hypothesis' [e.g., *O'Hara and Yoder*, 1967].

The latter hypothesis calls for the melting of a garnet lherzolite parent at about 80–100 km to produce a picrite liquid. High-pressure fractional crystallization of this melt in turn produces a variety of residual undersaturated, alkali-rich liquids, some of which are kimberlitic. The major problems of the fractional crystallization hypothesis are that it necessitates large volumes of melt and close association of kimberlite and basalt igneous activity [*Dawson*, 1971].

In the partial melt model, which is favored by many researchers [see *Dawson*, 1980], it is assumed that vapor-absent partial melting of a peridotite source rock occurs in the presence of high activities of $H_2O$ and $CO_2$. At great depths, below about 100 km, most of the volatiles are stored in carbonate and hydroxyl phases such as dolomite and phlogopite. These phases buffer the composition of the melt through a series of devolatilization reactions. The $CO_2$ and $H_2O$ released during the breakdown reactions become dissolved in the melt (vapor-absent melting). Experimental data, thermodynamic considerations, and geobarometric calculations on mantle xenoliths brought up by kimberlites suggest that kimberlite melts are generated by a small degree of partial melting of mantle peridotite in the presence of high activities of $CO_2$ and $H_2O$ at depths of about 120–180 km [e.g., *Eggler and Wendlandt*, 1979; *Wyllie*, 1979*a*, *b*]. Analyses of rare-earth and other trace and minor elements in kimberlites are consistent with the above model of kimberlite generation [e.g., *Wedepohl and Muramatsu*, 1979; *Frey et al.*, 1977]. To account for the enrichment in such species as K, Ti, Fe, and $H_2O$, *Boettcher et al.* [1979] suggested that the mantle lherzolite source rock underwent metasomatism before melting to produce alkali basalts and kimberlites.

*Harris'* [1957] zone refining model is another hypothesis that has been suggested to account for the generation of kimberlite melts, particularly for their enrichment in incompatible elements. In this model, magma rises slowly from deep in the mantle, remaining more or less in equilibrium with the surrounding wallrock. By simultaneous solution and crystallization during the magma's ascent, the incompatible elements are enriched in the liquid. It has been suggested that potassic basalts and kimberlites might arise this way. However, the partial melting hypothesis still seems the most reasonable with regard to the petrology of mantle xenoliths, to experimental data, and to known volatile equilibria.

A further important effect of volatiles in the melt is that changes in devolatilization reactions with pressure are reflected in the compositions of the liquid and coexisting vapor. As pressure decreases, the melt becomes more volatile-rich and more silica-undersaturated (because of the polymerizing effect of $CO_2$). Therefore, it is possible to develop different compositions of melts from the same mantle peridotite source, at different pressures or depths. Phlogopite and carbonate together can buffer near-solidus peridotite melts between about 80 and 230 km. At lower pressures the melts are carbonatitic, and at higher pressure are kimberlitic [*Wyllie*, 1979*a*]. *Wyllie* [1979*a*] accounted for the localization and rarity of kimberlites by suggesting that the necessary $CO_2$-$H_2O$ accumulations are rare in the mantle. *Eggler and Wendlandt* [1979] advanced a tectonic explanation for the localization of and rarity of kimberlites. They suggested that although melts of appropriate compositions may be abundant at depth, the proper tectonics for intrusion may be rare, because conditions are generally unsuitable for the rise of a diapir of mantle peridotite (Figure 3).



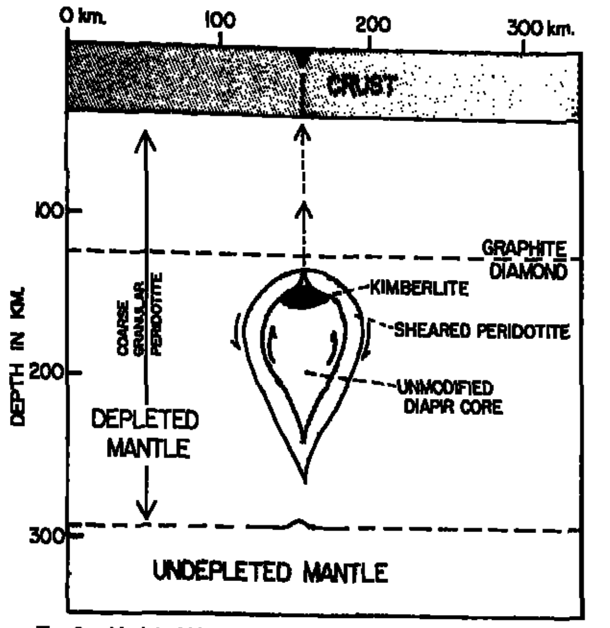


Fig. 3. Model of kimberlite melt generation during diapir upwelling; according to Green and Gueguen as amplified by *Mercier* [1979]. If the diapir model is correct, kimberlite melt is in equilibrium with the immediately surrounding peridotite. Thus, devolatilization reactions in the diapiric peridotite affect the kimberlite melt. Composition of the latter is buffered by the diapir system.

The abundance of and composition of the volatiles associated with kimberlite affect both its early magmatic evolution and its emplacement. There is some question concerning at what depth a separate volatile phase forms in the kimberlite melt, *Wyllie* [1979*b*] favoring the separation at great depth (80–100 km) and Eggler (in a talk at the Cambridge Kimberlite Symposium II, 1979) suggesting much shallower depths. It is possible that a volatile phase does not develop until the melt is within a few kilometers of the surface, that is, not until explosive breaching occurs in the kimberlite pipe. We do have some constraints on the rate of rise of kimberlites, because their included mantle xenoliths appear relatively unaltered in many cases [e.g., *Boettcher et al.*, 1979; *Mitchell et al.*, 1980]. The degree of fractionation shown by kimberlites, particularly in their opaque oxide phases, suggests that the melts did not rise explosively from depths of 80–100 km [*Pasteris*, 1980*a*].

Near-surface phenomena in intruding kimberlites also have been interpreted in more than one way. Part of the problem is that the various models may have been derived for different vertical levels within the diatreme, or explosive pipe. *Clement* [1979] recognized the following three depth zones in a kimberlite pipe (see cover, part A, this issue): crater (300–350 m depth, very brecciated, often with pyroclastic and partly eroded kimberlite); diatreme (extending 1–2 km beneath the crater, with steep walls, containing kimberlite tuff breccias with abundant country-rock xenoliths, showing little thermal metamorphism of the inclusions); and root zone (extending 0.5 km or more, enclosed by very irregular walls strongly influenced by existing fractures, containing abundant contact breccias of shattered wallrock and extensive alteration of inclusions). In most areas, the crater zone has been removed by erosion, but the brecciated, inclusion-rich diatreme zone may be exposed at the surface. However, it is in the root zone that one best sees the igneous nature of the kimberlite (e.g., definite phenocryst to matrix relationships, euhedral crystals, zoned crystals, thermal alteration of inclusions (Figure 1)).

Thus, it is clear that kimberlites have a magmatic (formerly liquid) component. However, much solid fragmental material is involved, particularly at shallow depths in the pipe.

*Clement* [1979] suggested that volatile release in the melt must occur before the kimberlite breaches the surface to explain the well-developed root zone. During breaching, fluidization (rapid devolatilization, entrainment of solids and liquids) occurs near the surface and works its way back down the pipe, accounting for the extensive brecciation and low degree of thermal metamorphism associated with the upper reaches of the diatreme.

## Ongoing Investigations Into Kimberlite Generation and Significance

A host of questions concerning the details of kimberlite origin and the relationship between kimberlites and their ultramafic xenoliths follows the recognition that kimberlites are mantle-derived igneous rocks and not just mantle-derived breccias. Several important points must be recognized before attempting a petrologic interpretation of a kimberlite. The silicate phases frequently have been partially or fully serpentinized, carbonated, or otherwise altered. The usefulness of bulk-rock chemical analyses is thus limited, and the number and variety of mantle- and crust-derived xenolithic inclusions make analysis interpretations even more questionable. In addition, individual mineral phases in the kimberlite represent xenocryst, phenocryst, and matrix grains. As stated previously, kimberlites have a story to tell, but detailed petrography, as well as chemical analysis, is necessary to interpret the rocks.

### *Mineralogical Studies*

Extensive literature has developed on opaque phases, predominantly spinels and ilmenite, in kimberlites from South Africa, Canada, and the United States [e.g., *Haggerty*, 1975; *Mitchell*, 1979*a*; *Boctor and Meyer*, 1979; *Pasteris*, 1980*a*, *b*]. Opaque oxide phases are especially useful in kimberlite analysis because they are relatively unaffected by late-stage alteration; they are almost ubiquitous; and their compositions are sensitive to changes in chemistry, temperature, and oxygen fugacity in the magma. Zoning in and complex reaction rims around opaque oxide phases (Figure 2) have led petrologists to try to interpret kimberlite fractionation trends and the possible petrologic differences between kimberlite varieties. For instance, *Pasteris* [1980*b*] inferred from the compositions of indigenous and xenocrystic ilmenite grains in kimberlites that kimberlites are not derived from the melts that produce abundant single-phase mantle xenoliths called megacrysts. *Haggerty* [1975] and *Mitchell* [1979*a*] have used the compositions of spinels in the kimberlite groundmass and in reaction rims on ilmenite macrocrysts to infer fractionation trends (including changes in $fO_2$) in kimberlites.

Another possible indicator mineral for changing melt composition and $fO_2$ (reflected in $Fe^{2+}$-$Fe^{3+}$ ratios) is phlogopite, which like olivine occurs as xenocryst, phenocryst, and groundmass grains. Complex optical and chemical zoning patterns occur in kimberlitic phlogopites [e.g., *Boettcher et al.*, 1979] and may reflect mineralogic changes no longer observable in the rock [e.g., *Pasteris*, 1980*a*]. The presence of and composition of phlogopite in these rocks also is of interest because of the role phlogopite may play in the melting of the peridotite parent rock and because of its possible role in the inferred process of mantle metasomatism [e.g., *Boettcher et al.*, 1979].

Totally fresh olivine grains are rare in kimberlites. However, *Boyd and Clement* [1977] analyzed unserpentinized olivines from part of the De Beers Pipe in South Africa and observed the following: (1) Texturally different grains (xenocrysts and phenocrysts) have distinctive but overlapping ranges in composition ($Fo_{84-93}$); and (2) the grains usually have homogeneous cores, but their rims (outer 150 μm) show Fe enrichment or Mg enrichment. *Boyd and Clement* [1977] interpreted the Mg enrichment as due to metasomatism rather than to growth zoning.

There are several types of intriguing intergrowths among oxide phases and between oxide and silicate phases in kimberlites (Figure 4). Some of these may indicate reactions occurring in the kimberlite melt. Several such intergrowths were discussed in May 1981 at the AGU Spring meeting. (Abstracts of the AGU talks referred to appear in *Eos, 62* (17).) Kissling et al. examined possible reactions giving rise to rims of titanomagnetite and perovskite on ilmenite. Tollo et al. did experimental studies on the mineralogically intriguing rutile-ilmenite intergrowths, which have defied explanation for many years (Figure 4*a*). They believe these samples may represent breakdown of a $Ti^{3+}$-armalcolite phase, the presence of which indicates lower $fO_2$ values than previously postulated for kimberlites. Hunter and Taylor documented what appear to be products of garnet breakdown in inclusions in a kimberlite from southwestern Pennsylvania. The reaction products include a glass containing skeletal olivine and euhedral spinel grains as well as symplectic intergrowths of clinopyroxene, orthopyroxene, and spinel. Similar vermicular spinel-silicate intergrowths (Figure 4*c*) have been found in abundance in non-garnet-bearing mantle xenoliths and kimberlites, but their origin remains controversial [e.g., *Dawson and Smith*, 1975]. Schulze examined small inclusions of calcite, serpentine, and phlogopite in diopside megacrysts, and inferred that they may represent crystallization from occluded kimberlite liquid.

Indeed, assemblages from kimberlites and their included xenoliths provide a wealth of small-scale mineralogical

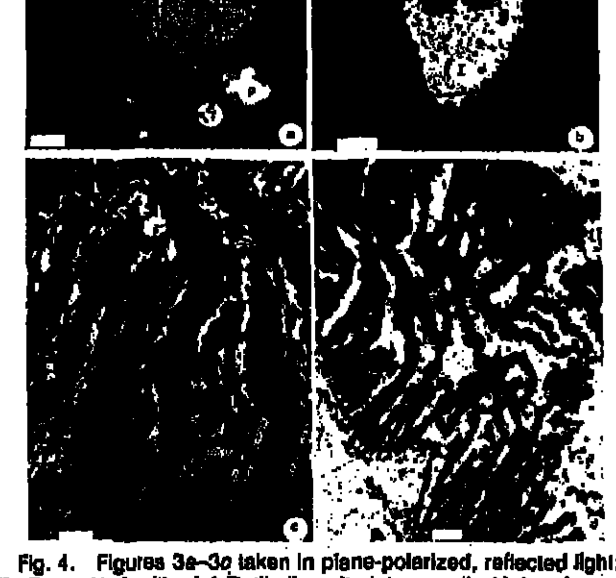

Fig. 4. Figures 3*a*–3*c* taken in plane-polarized, reflected light; De Beers kimberlite. (*a*) Rutile-ilmenite intergrowth. Major phase is light gray rutile with darker gray lamellae of ilmenite, oriented in four directions. Intergrowth rimmed by granular ilmenite, in turn mantled by granular titanomagnetite (T) and perovskite (P). Scale bar = 20 μm. (*b*) Large ilmenite (light gray; I) inclusion in phlogopite (dark gray). Small phlogopite inclusions (each with different optical orientation) within ilmenite. At least texturally suggestive of liquid immiscibility. Scale bar = 200 μm. (*c*) Spinel component of silicate-spinel symplectite. Spinel digits are zoned from chromite-rich central phase (dark gray) to magnetite-rich outer spinel (light gray). Scale bar = 20 μm. (*d*) Transmitted light view of symplectite of spinel (black) and altered silicate. Same intergrowth as in Figure 3*c*. Scale bar = 50 μm.

problems, many of which have much broader petrologic implications.

*Volatiles in Kimberlites*

More recent approaches to kimberlite genesis recognize the need to model mantle control of igneous processes. For instance, in mantle rocks oxygen fugacities approximating the quartz-fayalite-magnetite buffer are more reasonably assumed to be controlled by assemblages like enstatite-magnesite-olivine-graphite/diamond (the EMOG and EMOD buffers of [*Eggler et al.*, 1980]). Furthermore, in addition to $CO_2$ and $H_2O$, $CH_4$ now is being investigated for its effects on high-pressure melting of peridotite. Eggler and Baker found that methane not only depresses peridotite liquidus temperatures greatly, but also depolymerizes the melt and thus expands the stability field of olivine (as does water).

The recognition of other species in the postulated C-O-H-fluid in the mantle is important with regard to oxygen fugacity, volatile solubility in the melt, depression of melting temperatures, melt structure, and phase relations. The presence of methane in the mantle is supported by its inclusion in diamonds and (by inference) from the formation of graphite during serpentinization of kimberlite [*Pasteris*, 1981]. Eggler and Baker do not suggest that large quantities of methane exist throughout the mantle. However, they recognize for instance that in the presence of methane, eclogites could be produced at higher pressures than with only $CO_2$ and $H_2O$. They reason that this effect might account both for why diamonds are found in eclogites and why diamonds have methane inclusions. Furthermore, the presence of methane at mantle pressures and temperatures requires oxygen fugacities much below those of QFM (Eggler's estimate for most of the mantle), but it is possible that the mantle $fO_2$ is now more oxidizing than in the past, according to Eggler and Baker.

**Future Investigations of Kimberlite**

There is still a need for field exploration of kimberlites throughout the world to characterize better their tectonic, petrologic, and age relationships. In addition, several research groups continue to do basic petrologic and mineralogic characterization of kimberlites. Some of these groups and the geographic areas they have been investigating recently are as follows: Stephen Haggerty and coworkers (University of Massachusetts) in western Africa, Roger Mitchell (Lakehead University, Ontario) in northern Canada, Lawrence Taylor and coworkers (University of Tennessee) in Kentucky and Pennsylvania, the De Beers Geology Department (Kimberley) in South Africa, Barry Dawson (Sheffield, England), Peter Nixon (Leeds, England), and Jill Pasteris (Washington University, St. Louis) in South Africa and Missouri.

There is a need for more detailed geochemical analysis of kimberlites, but it must be in conjunction with careful petrologic interpretation. Analysis of confirmed indigenous kimberlite phases should put us well on the way toward making 'petrologic sense' out of these rocks and perhaps toward characterizing which types are diamondiferous and which are barren. Isotopic analysis of individual phases like serpentine and phlogopite provide a means of determining the fluid sources for the minerals (e.g., mantle- or groundwater-derived). Some analyses of the REE-rich phase perovskite were presented by *Boctor and Boyd* [1979], who showed that REE abundances differ greatly among the kimberlites. Analysis of the abundant groundmass phase perovskite may be another means of genetically classifying kimberlite types and may shed light on the nature of the postulated metasomatizing fluids that aid in kimberlite genesis.

For instance, *Basu and Tatsumoto* [1979] regarded kimberlites as derivatives of relatively undifferentiated deep mantle, owing to their chondritic Sm-Nd relationships. They suggested that carbonates controlled the Sm-Nd and other REE patterns in kimberlites. However, it seems likely that in many cases perovskite is a major REE carrier. One wonders how the Sm-Nd systematics of perovskite and apparently primary carbonates in kimberlite compare to those of the bulk rock. Have we previously been measuring the signatures of mixed sources in kimberlites?

What about the fluids associated with kimberlites, both those that predate the kimberlite melt (reacting with the rising peridotite diapir) and those that are evolved from the kimberlite as it rises and fractionates? As indicated above, some data are forthcoming from isotopic analysis and thermodynamic modeling of C-O-H-fluids. However, there may be useful information, at least on late-stage magmatic processes, locked in fluid inclusions in kimberlitic phases (especially in olivine). *Roedder* [1965] and *Murck et al.* [1978] reported abundant $CO_2$-filled fluid inclusions in olivine grains in mantle xenoliths. The latter authors inferred the presence of another gas, perhaps $SO_2$ or $H_2S$, in the inclusions. Kimberlite phenocrysts of olivine also contain fluid inclusions, although most of them appear secondary (J. D. Pasteris, unpublished data, 1981). Abundant evidence of late-stage serpentinization with accompanying graphitization and sulfidation in kimberlites [*Pasteris*, 1981] suggests that we should search for the presence of fluid species like $H_2S$ and $CH_4$ in these secondary inclusions. In addition, recent research has revealed the presence of $N_2$ gas in a wide variety of rock types, including deep-seated xenoliths (J. Touret, personal communication, 1981). Especially because $N_2$ is an abundant contaminant in diamond, nitrogen should be considered a possible component in fluid inclusions in kimberlite.

What about the broader questions on the mechanism of kimberlite genesis? For instance, does a protokimberlite melt develop in the mantle and give rise to the single-phase xenoliths called megacrysts (phenocrysts), and does this melt eventually fractionate into a kimberlite liquid [see, e.g., *Garrison and Taylor*, 1980]? On the other hand, is it possible that the melt giving rise to the megacryst suite is petrologically distinct from that producing kimberlites [see, e.g., *Pasteris*, 1980b]?

Where do kimberlites fit into the large-scale petrologic model of mantle dynamics? From where in the mantle does their high fluid content come? Anderson at the AGU Spring Meeting recently reviewed constraints on the early geochemical and geophysical evolution of the mantle. He noted that kimberlites are strongly enriched in the highly incompatible elements compared to midocean ridge basalts, but not so enriched in the less incompatible elements. Anderson questioned whether the kimberlites themselves might not be comprised of the fluids extracted from the mantle parent, leaving a depleted residue.

**Why Study Kimberlites?**

Kimberlites are an excellent source of mantle xenoliths and our least expensive deep-continental drilling program. Unfortunately, they do not keep the stratigraphy intact; nor do we know the exact location of the drill hole at depth.

Furthermore, kimberlites are themselves mantle-derived melts. Whereas mantle xenoliths provide information on solid-phase equilibria at depth, kimberlites may represent our best clues to fluid evolution in the mantle. Somewhere (in time and space) there is a petrologic-geochemical connection between kimberlites and their xenoliths (including megacrysts).

This review has emphasized mantle processes, but active research also proceeds on the deep crustal (e.g., granulite) xenoliths entrained by kimberlites. Study of the solid- and fluid-phase equilibria of this material has brought forth interesting questions about the nature and timing of the possible degassing of the upper mantle and how this has affected the stabilization and growth of continental crust throughout time [*Newton et al.*, 1980].

Detailed mineralogic studies of kimberlite have made us more aware of the sensitivity of individual phases such as spinel to changes in magmatic conditions. We are constantly reminded of the small scale on which equilibrium is maintained.

Even as theoretical geoscientists, we cannot ignore the fact that it is also from kimberlites that most diamonds are derived. After all, it was the lure of finding another 'Star of South Africa' back in the 1860's that led to the initial exploration for South African kimberlites and the desire for an internal source of diamonds that led to the discovery of the Siberian kimberlite fields by the Russians in the 1950's. It is singularly fortunate for us that the term 'barren' kimberlite means only that the rock has almost no diamonds, but not that it is in any way barren of geologic information.

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Jill Dill Pasteris received an A.B. in geology from Bryn Mawr College in 1974 and then spent a year in Heidelberg, Germany, studying ore microscopy under Paul Ramdohr. She returned to write her dissertation at Yale University (Ph.D., 1980) on opaque oxide phases in kimberlite. Pasteris is an assistant professor and resources geologist at Washington University, St. Louis. Her research interests include kimberlite petrology, sulfide phases and fluid inclusions in mantle xenoliths, the Precambrian iron deposits of Missouri, and Mississippi-Valley-type Pb-Zn-Cu deposits.





# News

## Galileo Mission To Jupiter

Jupiter has been visited four times: by Pioneers 10 and 11 in 1973 and 1974 and Voyagers 1 and 2 in 1979. Data from those missions will be expanded by the Galileo mission in 1985, which will be the first entry probe into Jupiter's atmosphere. Galileo will also include an orbiting observatory that will provide long-term detailed studies of the entire Jupiter system.

Components for the Galileo spacecraft, which consists of the orbiter and the entry probe, are nearing completion. The development model for the heat shield on the probe recently passed tests at the NASA Ames Research Center, Mountain View, Calif. NASA says that approximately 95% of the flight parts have been delivered, and the design for the two parts of the spacecraft and the mission are nearing completion.

The probe heat shield, which is made up of two pieces, will encase the Jupiter probe instruments. The front piece, a conical-shaped shield made from a carbon cloth treated in plastic resin (carbon phenolic), will be 10 cm thick at the nose and up to 125 cm in diameter. The rear piece will be composed of a slightly different material, nylon phenolic, because this lower-density material will save weight while providing adequate protection for the less severe afterbody heating environment.

When the probe plunges into Jupiter's atmosphere, it will be going 48.2 km $s^{-1}$, equivalent in speed to a trip from New York to Los Angeles in 1½ min. This entry speed will expose the probe to nearly 7 times as much radiation as the sun produces at its surface (42 kW/$cm^2$). Upon entry, aerodynamic braking by Jupiter's thick atmosphere will decelerate the probe with a force equal to 300 times the gravity of the earth.

During this extreme braking, the sacrificial front body shield will vaporize down to a centimeter. The vaporization of the carbon phenolic material will provide a heat-absorbing blanket to protect the instruments until, finally, a parachute will open and yank the remaining shields away. The probe then will have about an hour to make measurements of Jupiter's atmosphere.

Carbon phenolic was chosen for the outer layer because it absorbs large amounts of energy in the process of vaporizing. This material was used for heatshields on previous spaceflights, including the Pioneer Venus probes.

During the first 20 s of its entry, radiative and convective heating will bring the heat-absorbing gas layer around the probe to a searing 8,317°C. Radiative energy is produced by the hydrogen molecules of Jupiter's atmosphere breaking apart and recombining. Convective heating is caused by the friction of gases heated and compressed by the probe's supersonic shock layer as it descends through Jupiter's upper cloud layers. [Source: NASA]—*PMB*

## Synfuels: Oil Shale Gets a Boost

The Reagan Administration has approved federal loan guarantees and support prices for two major oil shale projects in Colorado. There are more than 30 companies involved in developing oil shale deposits in the Colorado-Wyoming area, most of which have applied for support from the United States Synthetic Fuel Corporation (Synfuels Corp.).

Under the Defense Production Act the Union Oil Shale project of the Union Oil Company and the Colony Shale Oil project run jointly by the Tosco and Exxon companies will receive federal loan guarantees and price supports. Both operations are located in the Peceance Creek Basin in western Colorado.

The Union Oil Company's plant will use a surface retorting system with an upflow kiln that uses a rock pump. The system was demonstrated by Union years ago in pilot plant operation. Union's contract includes production of 10,000 barrels (bbl) per day—7000 bbl diesel and 3000 turbine—to come on line by late 1983. Within 5 years after production begins, Union plans to increase production to 50,000 bbl per day. The contract is for 10 years.

Colony Shale Oil will use a Tosco-designed surface retort with a rotary kiln that has also had pilot plant demonstration. The Colony plant is intended to produce 47,000 bbl per day by the late 1980's. Exxon will finance two thirds of the $3 billion expected cost of construction. Federal loan guarantees will be made for Tosco's portion.

Extracting oil from oil shale is not difficult, current wisdom aside. By heating oil shale to approximately 500° C, oil has been recovered for use from oil shale in France and Scotland since the 1830's. In the late 1850's there were 55 oil shale plants in the United States. The problem of large-scale production is cost from the processing of large volumes of shale, both in underground and surface retorting systems. About 15% or so (up to 60%) of the volume is usable petroleum, but in the heating process the shale expands, and its volume increases by 15–20%. The spent shale presents a disposal problem because of its volume and because of its possible contamination of ground water by leaching. Large amounts of water are needed in oil shale processing, but the supply of water has turned out not to be of serious concern, according to the Department of Energy. In a recent lecture before the Potomac Geophysical Society (an affiliate of AGU), Stephen Zukor, then at DOE and now with the U.S. Synthetic Fuels Corp., stated '... water availability has generally been cited as a barrier to oil shale development ... [but] ... the water availability assessment by the Colorado Department of Natural Resources and other studies show that there is adequate water available. ...' Zukor pointed out that '... water policy and management is the real issue.' At this point the policy and management issues have not been addressed, and the many government agencies that are involved in any decision could produce enormous complexities. Until commercial plants are built, the policies and final standards remain uncertain.

Zukor points out that the largest barrier to starting a productive shale oil industry is the initial cost of $2–3 billion for a commercial plant that the federal government has now supported. The economic effects to western Colorado will be immense. He sees that the problems of the processing water requirements are difficult but solvable. 'Water management' means obtaining seniority of water rights from various water projects including some rights of the Bureau of Reclamation. The availability of water will be seasonal, dependent on runoff and flow of the Colorado River. Alternative supplies have been identified for dry months, but the system remains untested. Disposal of spent shale requires a technology of its own. The surface retorting waste can be handled adequately by restoring mineral pits and by grading excess into abandoned areas. The environmental management of in situ 'burned out' underground retorts that could be filled with ground water may turn out to be more difficult. It is hoped that a coordinated Federal policy involving the departments of Energy and Interior and the Environmental Protection Agency will evolve as oil from shale production begins during this decade.—*PMB*

## 1981 Water Year: Dry Streams

More than three fourths of the nation—stretching in a broad band from California east through the Great Plains and blanketing the southeast—experienced a dry 'water year,' according to the U.S. Geological Survey, Department of the Interior.

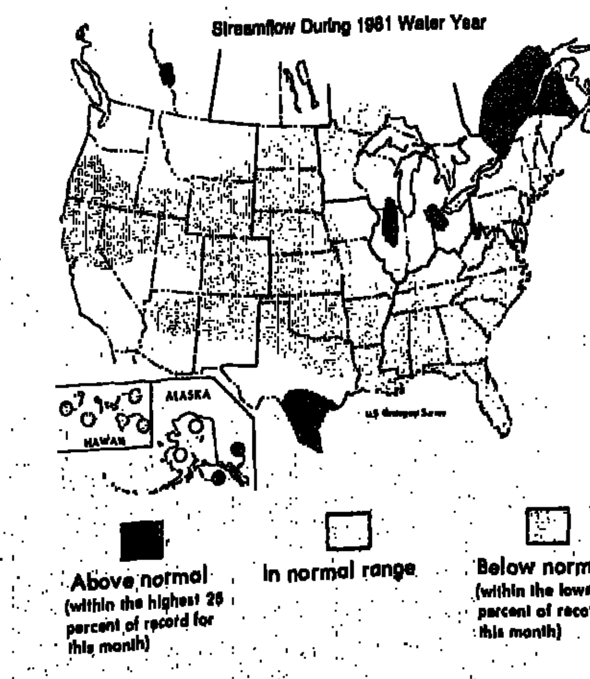
USGS hydrologists said that over the past 12 months, streamflow averaged well below normal—within the lowest 25% of record—in all or parts of 39 states. Over 60% of the key USGS index gaging stations across the country showed well below normal average streamflow for the water year.

The water year used by hydrologists runs from October 1 to September 30 of the following calendar year and is designed to follow roughly the growing season and to begin and end during a period of low streamflow.

The southeast was one of the most severely affected areas during the 1981 water year, where below normal streamflow persisted for many months over a broad area from Virginia south to Florida and west to Mississippi. USGS hydrologists said that 92% of the key index stations in the southeast reported overall water year streamflow in the well below normal range, within the lowest 25% of record.

The water year began with streamflow conditions nationwide generally in the normal range. Low-flow conditions developed last winter and began spreading to more and more sections of the country. By March 1981, midway through the water year, more than three fourths of the index stations averaged below-normal flows. The nation's streams recovered somewhat during the last half of the water year, and by September, conditions were generally in the normal range again, except in the southeast and parts of the Rocky Mountain states where low flows persist.

Reflecting the low-flow conditions that persisted in large areas of the country during the 1981 water year, combined flow of the nation's 'Big Five' rivers—Mississippi, St. Lawrence, Ohio, Columbia and Missouri—averaged 682 billion gallons a day (bgd), 12% below normal and the lowest flow since the 1977 water year. The Big Five account for stream runoff in about half of the conterminous United States and provide hydrologists with a quick, useful check on the health of the nation's water resources. The following are the 1981 water year flows of the Big Five: Mississippi River near Vicksburg, Miss., 282 bgd, 24% below normal; Columbia River at The Dalles, Ore., 119 bgd, 5% below normal; St. Lawrence River near Massena, N.Y., 170 bgd, 9% above normal; Missouri River at Hermann, Mo., 44 bgd, 14% below normal; and the Ohio River at Louisville, Ky., 68 bgd, 4% below normal. (Photo credit: U.S. Geological Survey, Department of the Interior.)




## Hydrology Manpower

The number of people qualified in groundwater studies 'must more than double over the next 10 years' if the United States is serious about dealing with groundwater contamination, according to David W. Miller, senior vice president at Geraghty & Miller, Inc., consulting groundwater geologists and hydrologists based in Syosset, N.Y.

Between 3500 and 5000 people are involved in developing and protecting groundwater resources, he told a groundwater-protection seminar earlier this month. 'That number must grow to between 10,000 and 15,000 people if federal, state and local governments, industry, and the public are serious about minimizing the types of activities that took place in the past and taking constructive steps toward protecting groundwater resources for the future,' Miller said.

Soil scientists, geophysicists, geological engineers, geochemists, and scientists in other related fields of geology and engineering will be vital in protecting and developing groundwater resources, he added.

## Minority Participation in Earth Sciences

The U.S. Geological Survey recently appointed Ann Nefcy as coordinator of the Minority Participation in the Earth Sciences (MPES) Program for the Central Region, which encompasses Arkansas, Colorado, Iowa, Kansas, Louisiana, Missouri, Montana, Nebraska, New Mexico, the Dakotas, Oklahoma, Texas, Utah and Wyoming. In the past, the USGS has assisted in the establishment of earth science programs and the strengthening of existing programs at colleges and universities with substantial minority enrollments. In addition, MPES assists young students who aspire to careers in earth sciences.

AGU members in the Central Region who are interested in learning about MPES are urged to contact Nefcy at the USGS, Box 25046, MS 101, Denver Federal Center, Denver, CO 80225 (telephone: 303-234-4472).

## Geophysical Events

This is a summary of *SEAN Bulletin, 6*(9), September 30, 1981, a publication of the Smithsonian Institution. The complete bulletin is available in the microfiche edition of *Eos*, as a microfiche supplement, or as a paper reprint. For the microfiche, order document number E81-009 at $1.00 from AGU, 2000 Florida Avenue, N.W., Washington, D.C. 20009. For reprints, order *SEAN Bulletin* (give dates and volume number) through AGU Separates: $3.50 for the first copy for those who do not have a deposit account; $2 for those who do; additional copies are $1.00. Order must be prepaid.

*Volcanic Events*

Mt. St. Helens (Washington): Minor ash emission; slow deformation.
Pavlof (Alaska): Ash clouds; lava flow; seismicity (entire report reproduced).
Shishaldin (Aleutians): Plumes accompany eruption at nearby Pavlof (excerpt of report reproduced).
Kavachi (Solomon Islands): Bubbling and discolored water.
Paluweh (Indonesia): Lava dome destroyed; pyroclastic flows (special report in past issue of *Eos*).
Colima (Mexico): New lava dome in summit crater; activity since 1976 summarized.
Guagua Pichincha (Ecuador): Small phreatic explosion; felt earthquakes (special report in past issue of *Eos*).
Pagan (Mariana Islands): New vent in the summit crater; other Marianas volcanos quiet.
Langila (New Britain): Ashfalls; incandescent tephra; discontinuous tremor.
Manam (Bismarck Sea): Incandescent tephra ejected; ash emission and seismicity decline.
White Island (New Zealand): Little eruptive activity for 6 months; B-type events increase.
Sakurazima (Japan): Frequent explosions, mudlike ejection.
Etna (Sicily): Collapse in the central crater; ash ejection (entire report reproduced).

*Pavlof Volcano, Alaska Peninsula, Alaska, USA (55.42°N, 161.90°W); Shishaldin Volcano, Unimak Island, Aleutian Islands, Alaska, USA (54.75°N, 163.97°W). All times are local* (GMT − 9 h). NOAA weather satellite images revealed an eruption plume emerging from Pavlof at 1030 on September 25. On the image returned at 1415, when weather clouds next permitted a clear view of the area, both Pavlof and Shishaldin (about 150 km to the southwest) were emitting plumes. At 1545, data from infrared imagery indicated that the temperature at the top of Pavlof's cloud was −55°C, corresponding to an altitude of about 9 km, and Shishaldin's cloud had reached 6–7.5-km altitude. The clouds drifted nearly due east and were still visible at 1945 when imagery showed a new plume originating from Pavlof (but not from Shishaldin). By 2215 the new plume had reached 9–10.5-km altitude and feeding from Pavlof appeared to be continuing. By 0415 the next morning the bulk of this plume had drifted to the southeast and appeared to be largely disconnected from its source, although faint traces of plume may have extended back to Pavlof. Fishermen in Pavlof Bay reported that activity continued through the night, dropping nearly 4 cm of ash on one boat. An ash sample from one of the boats was sent to the U.S. Geological Survey (USGS) in Anchorage. No certain activity could be distinguished on the satellite image returned at 0615, but there were unconfirmed reports of a renewed eruption at Pavlof by about 0700, and by 0930 the imagery again showed plumes from both Pavlof and Shishaldin. From infrared imagery, a temperature of −28°C was determined for the top of Pavlof's plume, indicating that its altitude was approximately 7.5 km. A Reeve Aleutian Airways pilot flying near Pavlof at 1000 observed a black eruption column and estimated the altitude of its top at roughly 6–7 km. He also reported incandescent material

on the west flank. On the next satellite image with clear visibility, returned at 1415, a faint plume that extended to the east southeast was still connected to Pavlof, but no activity could be seen at Shishaldin. No eruption clouds have been observed on the imagery since then, and there have been no reports from pilots of renewed activity.

A visit to the Pavlof October 2–3 by Egill Hauksson and Lazlo Skinla revealed that lava had been extruded from a vent about 100 m below the summit (elevation 2518 m) and had flowed down the north northwest flank to about the 600-m level. The lava covered an area of roughly 3 $km^2$ and was 6–7 m thick at the thickest portion of the flow front, which was not advancing. A sample of the lava was sent to the Lamont-Doherty Geological Observatory. No ashfall thicknesses could be determined because of redistribution by very strong winds.

A Lamont-Doherty seismic monitoring station 7.5 km SE of Pavlof's summit recorded occasional periods of harmonic tremor and an increase in the size of B-type events beginning about 2 weeks before the eruption. However, a few days before the eruption began, both the number and size of events decreased; only five discrete shocks were recorded between 1500 on September 22 and 1500 on the 23rd, and only two during the next 24 hours, as compared to an average background level of 15–25 per day. On September 25, the day Pavlof's eruption was first observed on satellite imagery, the seismographs recorded a few more discrete events and intermittent, very low amplitude harmonic tremor. Between 2000 on September 25 and 0300 on September 26, tremor amplitude increased gradually, and by about 0330, tremor was saturating the instruments. The strongest tremor was recorded between 0500 and 0900, then amplitudes began to decrease. However, tremor remained strong and continuous until 1220 on September 27, when it declined to several-minute bursts, between which discrete events could be observed. About 100 discrete events and lower-amplitude bursts of tremor were recorded during the 24-hour period ending at 1500 on September 28. As of October 5, B-type events and bursts of harmonic tremor were continuing.

Pavlof last erupted in November 1980, ejecting ash clouds that reached 11-km altitude, large lava fountains, and a long narrow lava flow that moved down the north flank (see *SEAN Bulletin, 5,* 11). Both the 1980 and 1981 eruptions occurred from vents high on the north flank, but it was not certain at press time whether these were the same vents. Shishaldin's last reported activity was in February 1979, when pilots saw unusually strong ash emission on the 14th, 15th, and 17th.

Information contacts: Thomas Miller and James Riehle, USGS, 1209 Orca St., Anchorage, Alaska 99501; Stephen McNutt and Egill Hauksson, Department of Geological Sciences, Columbia University and Lamont-Doherty Geological Observatory, Palisades, New York, 10964; Waldo Younker, NOAA/NESS, SFSS, Box 45, Room 518-F, 701 C St., Anchorage, Alaska 99513.

*Etna Volcano, Sicily, Italy (37.73°N, 15.00°E).* Collapse activity deep within Bocca Nuova, one of Etna's two central craters, has been frequent since the March 17–23 fissure eruption (see *SEAN Bulletin, 6,* 3). No fissuring or other evidence of surface collapse has been observed around Bocca Nuova. Explosions associated with the collapse activity ejected fine ash, caused strong ground vibrations 300 m from the crater, and could be heard as much as 10 km away. Plumes produced by this activity could sometimes be seen on the satellite images returned once daily by the NOAA 7 polar orbiter. Images returned shortly after noon on October 3 and 4 showed narrow, well-defined plumes extending about 75 km downwind from Etna. A smaller, less dense plume, extending outward only about 20 km, was present on the October 6 image.

Information contacts: John Guest, University of London Observatory, Mill Hill Park, London NW7 2QS England; Michael Matson, NOAA/National Earth Satellite Service, Land Sciences Branch, Camp Springs, Maryland 20233

### *Earthquakes*

| Date | Time, GMT | Magnitude | Latitude | Longitude | Depth of Focus | Region |
|---|---|---|---|---|---|---|
| Sept 1 | 0930 | 7.7 $M_s$ | 14.99°S | 173.17°W | shallow | Samoa Island |
| Sep 3 | 0536 | 6.6 $M_s$ | 43.59°N | 147.08°E | 46 km | Kurile Island |
| Sep 12 | 0716 | 6.1 $m_b$ | 35.67°N | 73.55°E | shallow | NE Pakistan |
| Sep 17 | 0823 | 6.6 $M_s$ | 22.53°S | 170.00°E | shallow | SW Pacific |

A local tsunami that measured 24 cm peak to peak followed the Samoan Islands earthquake by about an hour. The shock was centered at the north end of the Tonga Trench, about 200 km west of Pago Pago. Felt across northern Hokkaido, Japan, the September 3 event caused minor damage on Shikotan Island, about 25 km northwest of the epicenter, at the southern end of the Kurile Islands. The September 12 earthquake killed 212 persons, injured about 200, and left 17 missing. Several villages were destroyed and the city of Gilgit was extensively damaged. The September 17 event occurred in open ocean about 800 km southeast of the Loyalty Island region.

Information contacts: National Earthquake Information Service, U.S. Geological Survey, Stop 967, Denver Federal Center, Box 25046, Denver, Colorado 80225; Geological Survey of Pakistan, Quetta, Pakistan; Karachi Domestic Service broadcast, Karachi, Pakistan; United Press International; Moscow Domestic Service broadcast, Moscow, USSR.

### *Meteoritic Events*

Fireballs: Brazil, Czechoslovakia (2), British Isles (3), New Mexico, Pennsylvania

# New Publications

## Space Science Comes of Age: Perspectives in the History of the Space Sciences

Paul A. Hanle and Von Del Chamberlain (Eds.), Smithsonian Institution Press, Washington, D.C., xiii + 194 pp., 1981, $12.50 (paper) $22.50 (cloth).

Reviewed by David P. Stern

On March 23–24, 1981, the National Air and Space Museum of the Smithsonian Institution in Washington hosted a symposium on the history of the space sciences, and this book is one of the results. It contains nine articles covering various aspects of the main theme, prepared by the invited speakers, plus two reprints of material, which has already appeared in similar form elsewhere. Illustrations abound, with some articles devoting about equal space to pictures and to the text, and the volume is dedicated to the memory of Tim Mutch, NASA's Associate Administrator for Space Science, who died tragically the previous year on a mountain climb in the Himalayas.

It is a rather nonuniform book, and for a good reason: There exists no consensus about what exactly constitutes history of space science, neither among the contributors to this volume nor in the community of scientists and historians. Does a chronological review of missions, spacecraft, observations, and/or administrative decisions qualify? Some of the articles here give just that, and while such chronologies certainly do contain some necessary ingredients of history, the passive voice, so effective in dehumanizing the professional scientific literature ('it was found that . . .'), often takes over and makes the reader wonder what the real story was like.

At the other end of the spectrum, the collection contains personal accounts by Jastrow and Shoemaker, written in first person and quite explicit. Perhaps they come a bit closer to the mark, and though Jastrow's account of meeting Harold Urey and helping launch Apollo may arouse controversy, perhaps now other participants of that drama will also tell their sides of the story and leave it to the rest of the community to match the various accounts. Shoemaker's account is a brief one, and I for one hope that the author will return to it one day and expand it. There must be much more to the story of the geologists who dreamed of walking on the moon—those who did not fulfill their dream, like Shoemaker himself, and the one who did, Harrison Schmitt, who is now a U.S. senator.

However, what may be the best part in this collection belongs to neither of these classes, but is a reprint of Van Allen's first news conference of May 1, 1958, describing the discovery of the radiation belt. It is not a personal story, the style is scientific and detached, yet it manages to capture well the atmosphere of those early days, of the initial groping and puzzlement. The question-and-answer record makes it clear that the initial explanations were at best incomplete, that they were dominated by the analogy with the polar aurora, while no hint existed yet of albedo neutron decay or ring current protons or $O^+$ ions. Still, the deduction was clear and logical: This perhaps comes closest to the stuff of which 'real' history consists.

Two lucid reviews were contributed by professional science historians. Steve Brush surveys theories of the origin of the solar system, 1900–1960, a thorough exposition, which covers its subject well, though an afterword linking it to present-day views might have been appropriate. And Stewart Gillmor reviews the story of ionospheric layers up to about 1950, when the study of the earth's ionosphere entered a new phase with different emphasis (e.g., thermospheric chemistry), new tools, and perhaps a new cast of characters.

Other articles are by Lyman Spitzer, Jr., on UV astronomy; by Leo Goldberg on solar observations from space; by Herbert Friedman on early 'rocket astronomy,' in particular X rays (striking pictures!); by Richard Hallion on launch vehicles; by Pamela Mack on the Landsat project; and a review of space science by Homer Newell, adapted from part of his recent book *Beyond the Atmosphere: Early Years of Space Science.*

Taken together, it is a first step, or perhaps a collection of steps in different directions, trying to define and capture the image of a new scientific discipline that is still evolving. It is very much like a set of test drillings by a prospector, to determine whether the lode is there and whether it is worth extracting. On this point, at least, the answer seems clear: The lode exists, and it is an immensely rich one. It will reward handsomely those who will extract it, but the effort will have to go far beyond this modest beginning.

*David P. Stern is with the Laboratory for Extraterrestrial Physics, Goddard Space Flight Center, Greenbelt, Maryland.*

## Environmental Geology

D. R. Coates, John Wiley, New York, iv + 701 pp., 1981, $21.95.

Reviewed by Robert H. Fakundiny

The subject area of 'environmental geology' has needed a precise definition and a cogent argument to give it legitimacy among the other subdivisions of earth science. Donald R. Coates has aided the cause of legitimacy by providing this comprehensive and reasonably priced compilation of data, case histories, and philosophy. We still wait for a succinct definition, however.

The book has neither a stated specific audience nor a declared purpose; but seems to be a handbook, almanac, and history of environmental geology for the professional geologist and lay person that could also be used as an undergraduate-level college text. Although it may not succeed fully in either function, it does provide the reader with an overview of the impact geology has upon our lives. Prevalent philosophical statements and personal emphasis in the presentation of arguments pertaining to current environmental issues will probably make it one of the more provocative scientific books available.

The book contains over 700 pages of discussions with nearly 700 black and white illustrations and tables. It is divided into six parts: 'Fundamentals,' 'Geologic Resources and Energy,' 'Geologic Hazards,' the 'Human Modification of Nature,' 'Environmental Management,' and 'Synthesis and Epilogue,' accompanied by a glossary and six appendices giving the classification of rocks, the origin of mineral deposits, and a list of recent hazards and disaster events. Each of the six parts has an introduction with readings presented as several chapters, and each of the chapters (21 in all) has an individual introduction and readings list as well as a conclusion, called 'Perspectives.' Such a massive undertaking would normally take years to write. The subject matter, however, requires timeliness, and a large number of flaws suggest that this work was done quickly.

The long list of positive characteristics attests to Coates' talent for compilation, assimilation, and synthesis. The chapters on 'Historical Perspectives,' 'Energy and Fossil Fuels,' 'Energy: Alternative Sources,' 'Volcanic Activity,' 'Landslides,' 'Floods,' 'Engineering Impacts on Water Supply,' 'Coastal Environments,' 'Human Impacts on Soil,' and 'Weather, Climate, and Civilization' are comprehensive and enlightening. Technical quality is particularly high in some of Coates' own fields of expertise: geomorphology, surficial geology and soils, and case-history reviews. The numerous interspersed tables are pertinent and effective as supplementary data for the case histories. The scope of the book is ambitious, yet Coates is successful in mentioning almost every topic related to environmental geology. One way in which the usefulness of the text could be enhanced would be to add a comprehensive reference section that leads the reader to a primary source for the myriad case histories and interesting facts.

This book would be a worthwhile addition to every geologist's and environmentalist's library because it contains not only hundreds of short discussions of appropriate case histories related to each of the main topics, but also graphs and tables of data that effectively illustrate how geologic information is needed for many of today's decisions. Excellent accounts of geology's role in human history illustrate the delicate relationship between impact of people upon their surroundings and the perils of nature. Nowhere else have I seen in one volume so many tables of data useful for developing perspectives on environmental questions.

Several deficiencies are apparent in both the editing and printing and the text content. As examples, reproduction quality of photographs is poor, and type style and layout are inconsistent in later chapters. Also, many figure captions are incomplete or not explanatory, numerous inconsistencies exist between text tables and appendix tables, the table of contents is too abbreviated, and the glossary and index are incomplete. Several topics could have been discussed more fully, including governmental decision making, remote sensing of the environment, strategic minerals, geophysical techniques used for mineral-resource exploration and regional structural studies, state and Federal powerplant-siting laws, and the effects of trace element chemistry upon health. Some minor problems annoy more than offend; for example, several of the maps contain errors or fail to illustrate the intended idea, the definition of 'geotechnology' is inappropriate, the discussion of plate tectonics is weak, some facts are in error (asbestos is not a trace element, granite is not the most common intrusive rock, several cities larger than Denver are not on a major water body), and inaccuracies exist in both the presentation of the history of geologic studies pertaining to the hearings on the siting of Indian Point, New York, nuclear powerplants and the closing of the West Valley nuclear-fuels reprocessing plant in western New York.

A significant problem with the text content is the unbalanced emphasis given to contrasting environmental philosophies. One example is the discussion of mining impact, where a reprinted advertisement, including photographs, by a tractor corporation informs us early in the book, in the chapter on 'Mineral Resources,' that 'mining makes a mess of the countryside.' This visual presentation, followed by a section that discusses environmental problems of mining and another on extraction processes, suggests that mining is horrendous. The impression is not countered or contrasted until the end of the book, in a small subchapter on mine reclamation. Coates devises 10 basic concepts, some of which either seem unnecessary for discussion, such as 'environmental problems are universal,' or are open to debate, such as 'environmental decisions invariably involve and produce internal conflicts.' Several other concepts are used in questionable fashion, including Newton's second law of motion and the notion of feedback in systems. An interesting, and perhaps the most controversial, aspect of the book is Coates' boldness in debating environmental issues and presenting his personal views on managing the environment.

Coates, however, is convincing in this immense composition that environmental geology is a legitimate subject area of earth science. To provide the needed definition, perhaps we can draw from Coates' own words, in his tenth basic concept, where he illustrates what environmental geologists should do: 'Environmental geologists . . . should . . . articulate their findings and be willing to share their judgements in the public forum.' Coates has followed his own advice. Although the quality of the text is uneven, the book's good points so greatly outweigh the deficiencies that it will be valuable to all readers concerned with the environment and to all geologists interested in the influence their knowledge can have on the decisions made in both private and public sectors.

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## Who Pays for Clean Water? The Distribution of Water Pollution Control Costs

E. E. Lake, W. M. Hannemann, and S. M. Oster, Westview, Boulder, Colo., xxiii + 244 pp., 1979, $20.00

Reviewed by John E. Schefter

This is a report on a study of the costs of compliance with the 1972 amendments to the Water Pollution Control Act (P.L. 92-500) and of the distribution of these costs among different segments of society. Lake, Hanneman, and Oster set out to answer three questions (p. 1): 'Who will pay for water pollution control? How great will be the burden for different socioeconomic groups? Will the distribution of costs be equitable?'

The book is organized into five chapters. It begins with a review of the provisions of P.L. 92-500 and a brief history of water pollution control in the United States.

A discussion of problems of defining and measuring the equity of the distribution of water pollution control costs is provided in chapter 2, along with some information on the distribution of income in the United States. The authors propose to judge the equity of the distribution of the costs of the Act by estimating the extent to which the Act changes the equality of the distribution of income and by comparing the distribution of the costs with the 'distribution of the personal income tax, the total (Federal, state, and local) tax burden, the property tax, and the user charge burden' (p. 16). However, the distribution of the costs is compared only with that of the Federal personal income tax and the total Federal tax burden; the other comparisons are not presented.

In the third chapter the authors provide estimates of the municipal costs of complying with the Act and discuss both the methods that may be used to finance these costs and the resulting incidence of the costs. The distribution of the municipal costs of the Act is estimated based on assumptions as to methods of finance, which are, in part, based on survey results.

In chapter 4 the costs of industrial compliance with the Act are estimated under the assumption that the only pollution control alternatives available to industries consist of self-treatment or treatment in publicly owned facilities; the possibility that some industries might find changes in their production processes to be the most efficient means of compliance is not considered. The authors then provide estimates of the price increases resulting from the estimated industrial water pollution control expenditures. These price increases result in real income losses to consumers in that they can purchase fewer goods and services, given a fixed income. The magnitude of these annual real income, or welfare, losses is estimated for families in each income category on the basis of expenditure patterns within each category and price elasticities of demand.

In chapter 5, the estimates of the distribution of the costs of municipal compliance are combined with the estimates of the distribution of the welfare losses attributable to industrial price increases to obtain the estimated distribution of the total costs of compliance with P.L. 92-500. Estimates are provided by income, age, and racial groups (blacks versus the U.S. population as a whole) for 1977, 1980, and 1985. As it is assumed that full compliance will not be achieved until 1983, the estimates of the annual costs for 1985 are the only ones based on an assumption of full compliance.

In estimating the costs of full compliance, it is assumed 'that the requirements of the Act will be satisfied through private sector investments in both Best Practicable Technology (BPT) and Best Available Technology (BAT) and public sector investments in the amounts described in the 1974 Needs Survey Categories I, II, and IV-B' (p. 229). Needs Survey Categories I, II, and IV-B include traditional water-quality programs for treatment plants and interceptor sewers. Also provided are estimates of the distribution of costs for a more comprehensive program encompassing categories I-V, of the Needs Survey, which would require further upgrading of existing sewers and construction of new sewage and rainwater collection facilities. The authors do not consider the costs of Needs Category VI, which is concerned with expenditures for the treatment and/or control of stormwater runoff.

Two sets of estimates of municipal expenditures are derived: one set under the assumption that there would have been some level of expenditure on water pollution control in the absence of the Act and another under the assumption there would have been no such expenditures in the absence of the Act (zero baseline scenario). Because the authors assumed zero baseline industrial expenditures, the estimates of the total costs of the Act are based on the zero baseline scenario.

The authors conclude that 'the equity impacts of the Act appear small, and it does not appear that the poor will pay a disproportionate share of the costs' (p. 244). For the average family the estimated welfare losses attributable to industrial price increases are estimated to be an order of magnitude greater than the annual costs of municipal compliance. The distribution of these welfare losses 'hits the middle income groups particularly hard' (p. 228), though the incidence of the total pollution control costs is found to be 'roughly comparable to the distribution of the Federal tax burden' (p. 229).

The estimates of the distributional consequences of the Act must be viewed in light of the authors' simplifying assumptions. In particular, the authors ignored most of the macroeconomic consequences of the Act and chose to estimate the distributional consequences of only the 'direct' costs of complying with the Act. 'Other burdens, such as losses in GNP due to unemployment, reduced economic growth, loss of corporate profit due to inability to pass costs on . . . are excluded from the analysis' (p. 2). Neither do they consider any stimulative effect that the Act may have on certain sectors of the economy (for example, the producers of water pollution control equipment). Though the authors cannot be criticized for explicitly limiting the scope of their work, one might ask why they chose to estimate consumer welfare (or consumers' surplus) losses resulting from industrial price increases while ignoring profit (producers' surplus) losses due to inability to fully pass on these price increases.

A congenital critic would find much to quibble with, even legitimately question, in this book. But, given the authors' limiting assumptions and a degree of empathy with those faced with addressing such a complex problem, the research approach and results seem reasonable.

My main criticism is directed at the editorial quality of the report. The text is poorly written, redundant, and suffers from a lack of careful editing. Chapter 3, which occupies 150 pages of the 244 page text, is poorly organized; I had to keep referring to the Table of Contents for guideposts because the relevance of some of the material in this chapter is not always immediately evident. Not all of the references are sufficiently documented, and no bibliography is provided. Lake, Hanneman, and Oster have an interesting story to tell; unfortunately, it is poorly told.

Finally, it should be noted that the equity (however measured) of the Act will depend not only upon the distribution of its costs, but also upon the distribution of its benefits. Lake, Hanneman, and Oster provide a valuable look at who pays the 'direct' costs of obtaining clean water. The other half of the story remains to be told.

*John E. Schefter is with the U.S. Geological Survey, Reston, Virginia.*

**University of Utah: Faculty Positions.** The Department of Geology and Geophysics invites applications for four tenure track positions at the assistant to associate professor level.

1) *Economic Geology:* The specific area of expertise is open, however, preference will be given to candidates whose research interests are in geological, geochemical, or petrological characteristics of metallic mineral deposits.
2) *Sedimentary geology:* Applicants should have research interests in modern or ancient sedimentary basins.
3) *Seismology:* Applicants with backgrounds and specialties in seismic reflection, seismic imaging or theoretical seismology will be given preference.
4) *Potential fields:* Geophysicist with specialty in potential theory including gravity and magnetics. (The closing date for this position is January 31, 1982).

A Ph.D. or equivalent is required. The vacancies are to be filled by September 1982; the closing date for applications for positions 1–3 is December 31, 1981. Applicants should submit a vita, transcripts, a letter describing his/her research teaching goals, and names of five persons for reference to William P. Nash, Chairman, Department of Geology and Geophysics, University of Utah, Salt Lake City, Utah 84112.

The University of Utah is an equal opportunity/affirmative action employer.

**Position in Reflection Seismology/Rice University, Houston, Texas.** The Department of Geology plans to expand its geophysical program. Emphasis will be on reflection seismology. At this time applications are for the first of two open faculty positions. The successful applicant will help in the search for and selection of the second faculty member.

Your main responsibility will be to lead our department into the area of modern reflection seismology. Your main teaching and research interests should be in the acquisition and processing of reflection seismic data. You should also help in developing rigorous undergraduate and graduate curricula, which are supported by the traditional strength of the Math Sciences, Physics, and Electrical Engineering Departments at Rice. Enthusiasm to work with and undertake some joint projects with our geologists is essential.

Our plans are to acquire a computer system configured for high quality data processing. Substantial seed money for this facility is already in hand. Creative cooperation with the oil and geophysical industry in Houston, including a reasonable amount of consulting, is encouraged. Salary will be commensurate with qualifications and experience. Please send your curriculum vitae, a summary of experience in seismic processing, a statement of research interests, and names of three or more references to Dr. A. W. Bally, Chairman, Department of Geology, Rice University, P.O. Box 1892, Houston, Texas 77001. Application deadline—December 1, 1981.

Rice is an equal opportunity employer.

**City University of New York, (Brooklyn College): Faculty Positions.** The Department of Geology anticipates filling several tenure track positions at Full Professor level. (Salary range up to $43,400). Highly qualified individuals will be considered for distinguished appointments at an additional $5,000.

While candidates who have distinguished themselves in any field are welcome to contact us, we are particularly interested in openings in: energy resources (coal,petroleum), exploration geophysics, environmental geology or hydrogeology, coastal sedimentology, economic geology.

Successful applicants will be required to institute an active research program, supervise Master's and Ph.D. theses. Nominations and applications with current vitae should be sent to: Dr. S. Bhattacharji, Chairman, Dept. of Geology, Brooklyn College of City University of New York, Brooklyn, New York 11210. Positions open until filled.

Brooklyn College, CUNY, is an affirmative action/equal opportunity employer.

**Postdoctoral Awards in Ocean Science and Engineering.** Woods Hole Oceanographic Institution invites applications for 1-year postdoctoral scholar awards from new and recent doctorates in fields of biology, chemistry, engineering, geology, geophysics, mathematics, meteorology, and physics, as well as oceanography. Recipients of awards are selected on a competitive basis, with primary emphasis placed on research promise.

Fellowship stipend is $20,000. Appointees are eligible for group health insurance and a modest research budget. Recipients are encouraged to pursue their own research interests independently or in association with resident staff. Completed applications must be received by February 1, 1982 for 1982–83 awards. Awards will be announced in March. Write for application forms to: Dean of Graduate Studies, P.O. Box E, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts 02543.

Equal Opportunity Affirmative Action Institution.

**Structural Geologist/University of Wyoming.** The University of Wyoming, Department of Geology and Geophysics seeks applicants for a tenure track appointment in structural geology expected to be available beginning fall semester 1982 or earlier. Duties will include teaching of undergraduate and graduate courses in structural geology, supervising MS and PhD theses, and research in structural geology. Appointment at assistant professor level is preferred, but applicants requesting appointment at higher rank will be considered. Salary open. Applicants must have PhD degree and be versed in quantitative theory as well as field applications of modern structural geology and regional tectonics.

Applicants should provide, by January 1, 1982, a resume, three letters of reference, and a letter of application including a statement of current research interests and courses which the applicant feels qualified to teach. Applications should be sent to:

Dr. Robert S. Houston/Head
Department of Geology and Geophysics
University of Wyoming
Laramie, Wyoming 82071-3006.

The University of Wyoming is an equal opportunity/affirmative action employer.

**Supervisory Physical Scientist.** The Research Facilities Center (RFC) of NOAA in Miami, Florida, is seeking a senior level scientist to manage its Research Systems Group. The RFC equips, maintains, and operates aircraft, helicopters and ground based equipment specifically for atmospheric, oceanographic and environmental research. The incumbent will direct a group of scientists, engineers and technicians involved with collection, calibration, quality control, formatting, documenting and delivery of data to users of the RFC. This position is in the Competitive Service. The grade and entrance level salary of the position is GS-14, $37,871* per annum. Future salary adjustments are subject to the Merit Pay system. QUALIFICATIONS: BS or higher degree in meteorology, physics, math, oceanography, or the physical sciences. In addition, 3 years of professional experience which has equipped the candidate with the knowledges necessary to perform the above duties. SELECTIVE FACTORS: Applicants must have experience in a research and development environment and be capable of directing research in instrumentation physics, calibration techniques, advanced computer techniques and spectral analysis. Additional technical information may be obtained from Dr. C. B. Emmanuel (305)526-2936 or FTS 350-2936. TO APPLY: Current or former federal employees should submit SF-171 and CD-332 (Employee Appraisal). Form CD-332 may be obtained by calling (305) 361-4454 or FTS 350-1454. Applicants not employed by the Federal Government should submit a complete application package for "Physical Science Positions-1300". These forms may be obtained from the nearest Office of Personnel Management (OPM). ALL APPLICANTS MUST SUBMIT THEIR PUBLICATIONS RECORD. All applications should be submitted to NOAA/ERL Area Personnel Office, 4301 Rickenbacker Causeway, Miami, Florida 33149. Ref. Vac. No. NOAA/ERL 81-232. Applications must be received by November 13, 1981, to receive consideration. AN EQUAL OPPORTUNITY EMPLOYER. *Salary subject to increase due to October comparability adjustment.

**Seismologist/University of Utah.** Search extended: the University of Utah is expanding its geophysics program in the Department of Geology and Geophysics by adding a tenure track faculty member in seismology at the assistant to associate professor level. Applicants with backgrounds and specialties in seismic reflection, seismic imaging, and theoretical seismology will be given preference. The individual will be expected to teach undergraduate and graduate courses, and to pursue an active research program with graduate students. The department has modern teaching and research programs in geology and geophysics, and has close associations with the numerical analysis and data processing groups in computer science, electrical engineering and mathematics. The geophysics component of the department has strong research and teaching programs in seismology, electrical and electromagnetic methods, thermal properties of the earth, and potential fields. Current research in seismology includes seismological and earthquake research utilizing a new PDP 11/70 computer with plotter and terminals; monitoring of the Intermountain seismic belt by a 55 station telemetered network utilizing a new on-line PDP 11/34 computer; major experiments in seismic refraction profiling, investigations of seismic propogation from synthetic seismograms, application of inverse theory to seismology, seismic properties of volcanic systems and allied research in tectonophysics. The closing date for applications is December 31, 1981. A Ph.D. is required for this position. Applicants should submit a vita, transcripts, a letter describing his/her research and teaching goals, and names of five persons for reference to William P. Nash, Chairman, Department of Geology and Geophysics, University of Utah, Salt Lake City, Utah 84112.

University of Utah is an equal opportunity/affirmative action employer.

**Petrologist-Economic Mineralogist/University of Oklahoma.** Applications are invited for a tenure-track position, effective September 1, 1982 at the assistant professor level, in petrology and economic mineralogy. The successful applicant is expected to teach graduate courses in his/her specialty, to help teach undergraduate courses in mineralogy-optics-petrography, and to pursue an active research program. Consulting and interacting with mining companies are encouraged.

The University of Oklahoma has made a major commitment to diversify the program in the School of Geology & Geophysics. As a result five tenure-track positions are open for the fall of 1982. Six new faculty were added to the School in the fall of 1981 (bringing the total full-time faculty to 15), and an additional six positions will be available during 1983–1985. A new building that will house the School is in the design stage, and the successful applicant will participate in equipping it.

The Ph.D. degree is required for this position. Preference will be given to petrologists with a strong chemistry background and with a demonstrated interest in the economic geology of metallic and non-metallic mineral deposits. Qualified applicants should arrange to send transcripts of all college and university work, resume, statement of research interests, and three letters of reference to: Dr. Maryellen Cameron, School of Geology and Geophysics, University of Oklahoma, Norman, Oklahoma, 73019. Deadline for applications is December 31, 1981. Faculty members from the School will be interviewing at the November G.S.A. meeting in Cincinnati, Ohio, and at the December A.G.U. meeting in San Francisco, California.

The University of Oklahoma does not discriminate on the basis of race, or sex, and is an equal opportunity employer.

**Virginia Polytechnic Institute and State University: Senior Research Associate.** Interesting and abundant research and publishing opportunities, including new University-owned MDS-10 VIBROSEIS system, VAX 11/780 computer. Must have experience in theory and application of reflection seismology, and be interested in the application of reflection seismology to the solution of geologic problems.

Send resumes to: Dr. D. R. Wones, Department of Geological Sciences, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061-0796.

The University is an equal opportunity/affirmative action employer.

## The Caswell Silver Distinguished Professorship in Geology

### THE UNIVERSITY OF NEW MEXICO

The Department of Geology of the University of New Mexico is pleased to invite nominations or applications for the Caswell Silver Distinguished Professorship in Geology. This endowed professorship shall be awarded for periods of up to two years to earth scientists of distinguished accomplishment and international reputation. The professorship may be held by scientists of all specialities of the earth sciences in the broadest sense, and the major criterion for selection is that the individual be an active, productive leader in his or her field of research. The recipient must carry out a vigorous research program while in residence at UNM. The recipient is expected to interact with the faculty and students of the Department and to provide one or more seminars, in an advanced topic of his/her choice, during each academic year. The Foundation will provide unusually advantageous remuneration commensurate with the distinguished nature of the appointment. In addition, a generous allocation for travel and operating expenses (to include secretarial support, analytical services in department laboratories, use of field vehicles, and preparation of manuscripts) will be provided.

Applications or nominations should include a detailed resume and brief statement of major research accomplishments. Applications or nominations should be forwarded to:

Rodney C. Ewing, Chairman
Department of Geology
University of New Mexico
Albuquerque, New Mexico 87131

*The deadline for applications is January 1, 1982.*
*The Caswell Silver Foundation is an equal opportunity employer.*

**Research Position in Chemical Oceanography.** California Institute of Technology, Division of Geological and Planetary Sciences. The position of research fellow is being offered at Caltech for research in oceanography. Investigation of the isotopic composition of neodymium and rare earth abundances in sea water and sediments is now being carried forward. The mechanism of injection of REE into sea water will be studied. The differences in $^{143}Nd/^{144}Nd$ in various water masses [Piepgras *et al.*, Earth and Planet Sci. Lett. *45*, 223–236 and Piepgras and Wasserburg, Earth and Planet. Sci. Lett *50*, 128–138 (1980)] is now being carried forward as an exploratory venture in order to determine the origin and chemical behavior of REE in the ocean and the potential use of $^{143}Nd/^{144}Nd$ as a tracer. The laboratory facilities for sample preparation and analysis are fully functional and will be available. Applicants should have training in oceanography and a good perspective on general physical oceanographic models.

Send resume and references to Professor G. J. Wasserburg, Lunatic Asylum, California Institute of Technology, Pasadena, CA 91125.

Caltech is an equal opportunity/affirmative action employer (M/F/H).

**Geophysical Sciences.** Five faculty positions available in the next two to three years; two anticipated for fall 1982. Applications are invited for two tenure-track positions in geophysics, one in paleontology, one in micropaleontology, and one in sediment geochemistry. Ph.D. required by time of appointment. Successful candidates will be expected to teach graduate and undergraduate courses in areas of expertise, develop a research program, and participate in teaching introductory geology.

At least one of these positions may be filled at the Associate Professor rank or above. Salary range is $18,000–$35,000 depending upon experience and field of research. Applications are encouraged from individuals with industrial experience as well as recent graduates. Although all areas of geophysics will be considered, preference will be given to professionals in seismology and research interests in seismic stratigraphy and petroleum exploration.

Candidates for the paleontology position should have research interest in Cenozoic/Mesozoic biostratigraphy with preference given to those specializing in nannofossils. Candidates for the sediment geochemistry position should have interests in one or more of the following areas: organic geochemistry/geochemical petroleum explorations, or isotope geochemistry.

ODU is a state-supported University of 15,000 students situated in the metropolitan Hampton Roads area. Send vitae, a brief discussion of research interests, and arrange to have three letters of reference sent by February 15, 1982 to Dr. Randall S. Spencer, Chairman, Department of Geophysical Sciences, Old Dominion University, Norfolk, VA 23508.

An affirmative action/equal opportunity employer.

**Iowa State University of Science and Technology/Department of Earth Sciences.**

Applications are invited for two tenure track faculty positions. The rank for each is at the assistant or associate professor level, dependent upon qualifications. The successful applicant will be expected to develop strong research and graduate student programs. Teaching duties will include undergraduate and graduate courses in the areas of expertise.

*Mineral Resources/Economic Geology:* One position is in mineral resources/economic geology. An applied field orientation is preferred. Iowa State has established a Mining and Mineral Resources Research Institute and an interdepartmental minor in Mineral Resources in order to support and develop research and education in this area. In addition to the appointment in the Department of Earth Sciences there will be full opportunities to interact with these programs.

*Geomorphology:* The second position is in the general field of geomorphology. Additional expertise in an area related to geomorphology, such as groundwater, engineering geology or remote sensing is also desired. A person with an applied field orientation is being sought.

Each appointment will be on an academic year basis. Opportunities are available for summer teaching appointments. Salaries will be commensurate with qualifications. Application deadlines for both positions are February 15, 1982; later applications will be accepted if a position is not filled. Positions are both currently available and are expected to be filled no later than fall, 1982. For application information please write to:

Bert E. Nordlie
Department of Earth Sciences
253 Science I
Iowa State University
Ames, Iowa 50011

Iowa State University is an equal opportunity/affirmative action employer.

**University of Wisconsin-River Falls: Structural Geologist/Geophysicist.** Applications are invited for a tenure track position in Geology. Preference will be given to those candidates with emphasis in structural geology or general geophysics. However, other emphases will also be considered. The Ph.D. is required, and a desire to teach is essential. Academic rank and salary are dependent upon experience of the individual. Course responsibilities will include physical geology lecture and laboratory, structural geology, and other upper division courses commensurate with background and training. Candidates should send a letter of application, resume, and three letters of recommendation to: Professor Samuel F. Huffman, Chairman, Department of Plant and Earth Science, University of Wisconsin-River Falls, River Falls, Wisconsin 54022. (715) 425-3345. The University of Wisconsin-River Falls is an affirmative action, equal opportunity employer. Final date for receipt of applications is January 15, 1982.

## Scripps Institution of Oceanography

### NUCLEAR GEOPHYSICS

Applications are invited for an assistant research physicist at the Scripps Institution of Oceanography, specializing in field and laboratory studies of volcanic gases and volatiles in rocks. Requirements include a Ph.D. with experience in rare gas mass spectrometry and extraction of gases from rocks, plus field work in geothermal and volcanic areas. Applicants with mountain climbing experience and ability to work at high altitudes—up to 19,000 feet—will be given preference. Experience in helium isotope measurements is important. Send resume and names of three references to H. Craig, Geological Research Division, A-020, Scripps Institution of Oceanography, La Jolla, CA 92093 by November 30, 1981.

*An equal opportunity/affirmative action employer.*



## POSTDOCTORAL FELLOWSHIP

### The Naval Postgraduate School, Monterey, CA.

We are seeking a recent doctoral graduate with an interest in geomagnetics and some background in geophysical instrumentation and computer data analysis. The candidate will be expected to participate in ongoing experimental program of sea floor magnetic measurements using the School's research vessel and remote land based station. Stipend competitive with current practice. For further information, contact Prof. O. Heinz, Dept. of Physics, Naval Postgraduate School, Monterey, CA, 93940, or call (408) 646-2116.

*NPS is an equal opportunity/affirmative action employer.*

**Purdue University.** The Department of Geosciences invites applications for a faculty position, starting January or July 1982, in the broad field of mineralogy-petrology-geochemistry. A Ph.D. is required and preference may be given to scientists with an established record of research. The Department has an automated electron microprobe, mass spectrometer and laboratory for stable isotope studies, full range of high temperature and high pressure equipment, including furnaces for controlled $fO_2$ experiments, as well as X-ray equipment. The successful applicant will be expected to participate in both the undergraduate teaching and graduate studies programs, as well as actively engage in research. Rank and salary are open but will be commensurate with qualifications.

Purdue University is a land grant, state supported institution committed to academic excellence, and is an equal opportunity/equal access employer. For further information please contact Dr. Henry O. A. Meyer, Dept. of Geosciences, Purdue University, West Lafayette, IN 47907 (Tel. 317-494-3271). Closing date for applications is November 10, 1981.

**Seismologist.** Applications are invited for a postgraduate research position in seismology at the Scripps Institution of Oceanography. Applicants specializing in all areas of seismology will be considered, although preference will be given to recent graduates interested in seismic wave propagation, particularly as applied to the oceanic environment and digital signal processing. The position has a duration of one year, with the possibility of extension to two years, and an annual stipend of $18,360. Please send resume and three references to either Dr. Thomas H. Jordan or Dr. John Orcutt, A-015, Geological Research Division, Scripps Institution of Oceanography, La Jolla, CA 92093, prior to 1 December 1981.

Scripps Institution of Oceanography, University of California, San Diego is an affirmative action/equal opportunity employer.

**Instrument Analyst/Staff Research Associate III.** Job # 81-08-23. Oversee computer-automated wave-length dispersive XRF spectrometer. Minimum qualifications: two years analytical experience or equivalent academic background, preferably but not necessarily with XRFC or NOVA computer. Duties include: maintenance and repair of equipment; software development in FORTRAN for on-line minicomputer; participation in design and evaluation of strategies for analyzing trace metals in geological materials; and instruction of users. After first year, opportunity exists for personal research as time permits. Applicants should list equipment and applications with which they're experienced, and responsibilities therewith. Salary $1755/month.

Apply to Personnel Office, University of California Santa Cruz, 1156 High Street, Santa Cruz, Ca. 95064 no later than November 1, 1981.

**Structural Geology/University of Illinois at Champaign-Urbana.** (Search reopened) The Geology Department is seeking a structural geologist for a tenure-track (assistant professor) faculty position. A Ph.D. is required. Salary open. The successful candidate will be expected to teach advanced undergraduate and graduate courses in structural geology and establish a research program. For equal consideration, applications, including the names of three referees, should be sent by February 1, 1982 to Dr. D. E. Anderson, Department of Geology, University of Illinois, 245 Natural History Building, 1301 West Green Street, Urbana, IL, 61801-2999, (217) 333-6713.

Position to be filled by September 16, 1982.

The University of Illinois is an affirmative action/equal opportunity employer.

**Director: Geodetic Survey, NOAA.** The National Oceanic and Atmospheric Administration (NOAA) announces a Senior Executive Service Vacancy for the position of Director, Geodetic Research and Development Laboratory (GRDL) in the National Geodetic Survey, a component of the National Ocean Survey. The duty location is Rockville, Maryland. The salary range is $47,889–$50,112.50 per annum. Duties include providing technical and administrative supervision over employees and activities of GRDL; advising officials on the state of scientific knowledge in geodesy and making recommendations for research and development; exercising scientific and technical knowledge of contributing publications to professional journals and making presentations at national and international meetings; and advising and consulting scientists and executives in improvement of geodesy and related fields. Experience in management of scientific programs, geodesy, and solid earth sciences is required. Apply to: NOAA/NOS-6001 Executive Boulevard, Rockville, Maryland 20852. Attn: MB/PER15:TR

NOAA is an equal opportunity employer.

**Faculty Positions: The University of Alabama.** Applications are invited for three tenure track positions to be filled by Aug. 16, 1982. Two of the positions are expansion to accommodate a developing Ph.D. program. Applicants would be expected to teach undergraduate and graduate courses and actively pursue research. Ph.D. is required for retention of position. Assistant Professors preferred.

Position 1—Structural Geologist.

Positions 2 & 3—two from following interests: Hydrogeology, applied geophysics, low temperature geochemistry, economic geology/ore deposits, coal petrology, palynology, and physical sedimentology.

Closing date: Jan. 15, 1982. Send resume, transcripts, and three letters of reference to: Dr. W. Gary Hooks, Acting Chairman, Department of Geology, The University of Alabama, Box 1945, University, AL 35486.

The University of Alabama is an equal opportunity/affirmative action employer.

**Physical/Coastal Oceanographer.** The Center for Coastal Studies, Scripps Institution of Oceanography, has an opening for a physical, coastal oceanographer to conduct research in an ongoing program of innovative sediment management with emphasis on sediment response to the forcing functions of waves, winds and currents. The incumbent will select and publish on research projects into fundamental physics of coastal and harbor sedimentation and advance alternatives to current coastal engineering practices.

Appointments are for 1 or 2 years (renewable) at the postgraduate research or assistant research level. Qualifications for postgraduate research level are PhD or equivalent in physical oceanography and strong background in coastal processes and/or applied physical/mechanics with emphasis on granular/fluid mechanics. Appointment at the assistant research level requires the above qualifications and a demonstrated publication record. Salary from $18,138 to $25,200 commensurate with qualifications. Submit letter of interest including resume and at least three names of references before 1 December 1981 to: Dr. D. L. Inman, Director, Center for Coastal Studies, Scripps Institution of Oceanography, University of California at San Diego, La Jolla, California, 92093. Request position profiles at the same address.

An equal opportunity/affirmative action employer.

## National Science Foundation

### Director
### Division of Earth Sciences

The National Science Foundation is seeking qualified applicants for the position of Director, Division of Earth Sciences. The person selected will receive either a permanent, career appointment or a two-year rotational appointment. Persons interested in a leave of absence from their current employment are encouraged to apply for the rotational appointment. This position is part of the Senior Executive Service with a salary currently limited by law to $50,112 per annum.

Duties of the position involve managing a division responsible for funding research in the earth sciences. Incumbent assesses research needs and trends, presents plans for future development, determines funding requirements, prepares and justifies budget estimates, balances program needs, allocates resources, oversees evaluation of proposals and recommendations for awards and declinations, supervises staff, and represents NSF to relevant external groups. Qualification requirements include 1) supervisory and managerial experience for the achievement of organizational objectives through subordinates; 2) a Ph.D. or equivalent professional experience or a combination of education and equivalent experience in the earth sciences or closely related field; 3) substantial research experience and strong evidence of scholarship in the earth sciences, or closely related field, including published research results; 4) experience in the planning of multidisciplinary research programs in the field of earth sciences; and 5) experience coordinating with representatives of scientific and academic communities.

Applicants should contact Margaret Cademartori on (202) 357-7857 to request announcement EPB 82-1 for a permanent appointment or announcement EPB 82-11 for a rotational appointment. Announcements contain qualification requirements as well as instructions concerning the preparation of the supplemental narrative required with the SF-171 as application. Send SF-171 and narrative to National Science Foundation, Executive Personnel Branch, Room 212, 1800 G Street, NW, Washington, D.C. 20550. (ATTN: EPB 82-1 or EPB 82-11). Applications must be received by January 15, 1982.

EQUAL OPPORTUNITY EMPLOYER

**Groundwater Hydrologist.** The Minnesota Department of Natural Resources, Division of Waters has a vacancy at the Principal Hydrologist level for an experienced groundwater hydrologist to provide leadership for a program of ground water studies and monitoring to support State Water allocation decisions and to provide quantitative assessments for planning and management purposes. Address inquiries and requests for application forms to: Sarah P. Tufford, DNR-Division of Waters, Third Floor Space Center Building, 444 Lafayette Road, St. Paul, Minnesota, 55101. Present salary range: $23,323 to $31,132 annually, subject to revision in the near future.

## EARTH SCIENCES

The Lamont-Doherty Geological Observatory of Columbia University invites scientists interested in any field of the earth sciences to apply for the following fellowships: two postdoctoral fellowships, each awarded for a period of one year (extendable to two years in special instances) beginning in September 1982 with a stipend of $22,500 per annum. Completed applications are to be returned by January 15, 1982. Application forms may be obtained by writing to the Director, Lamont-Doherty Geological Observatory, Palisades, New York 10964. Award announcements will be made February 26, 1982 or shortly thereafter. The Observatory also welcomes applications from candidates for postdoctoral research associate positions in this discipline.

**Research Associate: University of Arizona.** Applications are invited for a possible appointment as research associate in theoretical plasma astrophysics, space plasma physics and/or cosmic-ray physics. The successful applicant will be expected to spend a substantial part of his or her time working on problems in solar or interplanetary physics. Appointments will begin in summer 1982 or later. Applicants should possess a recently acquired Ph.D. in a relevant area of physics, astronomy, or planetary science.

Inquiries should be addressed to Professor J. R. Jokipii or Professor E. H. Levy, Department of Planetary Sciences, Lunar and Planetary Laboratory, University of Arizona, Tucson 85721.

Applications should be accompanied by a resume, complete bibliography, and at least two letters of recommendation from persons who are well acquainted with the applicant's background and potential. All material should be received by April 1, 1982.

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**Faculty Positions.** Arizona State University, Department of Geology. Applications are invited for two tenure-track faculty positions, one at the assistant professor level and one at the associate level, beginning in August of 1982. One of these positions requires a candidate with interests in applying modern solid state science to geological phenomena. The selected candidate should develop an active research program and may use the extensive opportunities offered by the Facility for High Resolution Electron Microscopy at ASU. Teaching duties will include undergraduate mineralogy. Candidates for the other position should complement and extend existing strengths in the department. Possible areas include low temperature geochemistry, heavy isotope geochemistry, solid earth geophysics, tectonophysics, and related fields. The ability to use modern techniques in both field and laboratory studies and to integrate diverse approaches is highly desirable. Please send a detailed statement of research and teaching interests and a resume with names of four references to David Krinsley, Department of Geology, Arizona State University, Tempe, AZ 85287, by January 15, 1982.

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**Geophysical Fluid Dynamicist/Physical Oceanographer.** Applications are solicited for a junior faculty position in ocean physics or dynamics to begin in the academic year 1982–83. Areas of interest to the Department include analytical, numerical and laboratory modeling of physical processes and phenomena in the sea.

Yale University is an equal opportunity/affirmative action employer and encourages women and members of minority groups to compete for this position.

Curriculum vitae, publications, and the names of three or more referees should be sent by 31 December 1981 to: Robert B. Gordon, Chairman, Department of Geology and Geophysics, P.O. Box 6666, New Haven, CT 06511.

**University of Tennessee, Knoxville/Faculty Positions.** The Department of Geological Sciences (Main Campus of the UT System) invites applications for two or three tenure track teaching/research positions effective September 1, 1982.

The appointments will be at the assistant or associate professor level in:

1. Sedimentology or Low-Temperature Geochemistry
2. Metamorphic Petrology or Mineralogy.

The Ph.D. is required. Duties will include pursuit of an active research program as well as teaching and advising at graduate and undergraduate levels. Preference will be given those with documented research capabilities. Applicants will be interviewed at the Cincinnati G.S.A. meeting. Send resume (including transcripts) and names of 3 referees to: Thomas W. Broadhead, Search Committee, Department of Geological Sciences, University of Tennessee, Knoxville, TN 37916. Application deadline, January 15, 1982.

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**Field Research Positions.** The Exploration Research Laboratory of the Colorado School of Mines may have openings for a field party manager and/or an assistant field party manager on or about January 1, 1982. Position level will be negotiated based on qualification. This position involves, principally, seismic data acquisition but the person may participate in a wide range of field activities including resistivity, gravity and magnetics, etc. This is an opportunity to participate with a large geophysics research and development program. Specific responsibilities include planning and coordination of field work, training of crew members, and supervision of pre-processing. The position is most challenging and offers wide scope for initiation and acceptance of responsibility. Interaction with industry professionals, ERL staff, and faculty members of the Department of Geophysics is required. It is a position for growth, and challenge. A bachelors or masters degree is required for each of the positions. Field crew experience would be helpful. Ability to direct subordinates, interface with diverse groups, and communicate results is essential. Extensive field time is required for the Assistant Field Manager. Significant field time is required for the Manager. Schedules are not firm and are subject to research commitments and research time frames. Typical academic environment fringe benefits are available. If interested in further details or in submitting an application, contact Dr. James K. Applegate, Director, Exploration Research Laboratory, Colorado School of Mines, Golden, Colorado 80401.

The Colorado School of Mines is an affirmative action-equal opportunity employer.

STUDENT OPPORTUNITIES

**Graduate Research Assistantships in Physical Oceanography.** Opportunities for graduate study with Research assistantship available for students interested in M.S. or Ph.D. programs. A summer program with stipend is open to college juniors. Write: Douglas Caldwell, School of Oceanography, Oregon State University, Corvallis, OR 97331.

**Graduate Teaching & Research Assistantships/University of Houston.** Graduate teaching & research assistantships available to qualified persons interested in Space Physics at the University of Houston. Our experimental program features rocket & balloon-borne studies of the ionosphere & magnetosphere-ionosphere coupling. Emphasis has been on active experiments, most recent being a rocket-balloon campaign at Siple station, Antarctica in December 1980. Future work includes a study of pulsating aurora & participation in Waterhole II, an auroral quenching experiment. The theoretical program is on plasma waves in the solar wind & modeling of phenomena related to current experiments. Assistantships for first year students begin at $600 mo along with out of state tuition waivers. Graduate Chairman, Physics Dept., University of Houston Central Campus, Houston, TX 77004. EOE

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# Meetings

### Chapman Conference: Rock Discontinuities

'Discontinuities in Rock, Their Role and Significance in Geologic Processes,' an AGU Chapman Conference, will be convened by Lawrence Teufel and Robert Riecker at Bishop's Lodge near Santa Fe, New Mexico, on May 3–6, 1982. Sessions will cover mechanics of formation and characteristics, constitutive laws and deformational processes, geophysical phenomena, hydraulic properties, and mechanical and hydraulic modeling.

Those interested in attending should contact Teufel, Geomechanics Division 5532, Sandia National Laboratories, Albuquerque, NM 87185, or Riecker, Los Alamos National Laboratory, Geosciences Division Office MS 570, Box 1663, Los Alamos, NM 87545. To ensure the maximum interchange of ideas, attendance will be limited; participants will be selected from those applying. Deadline for application is December 15.

AGU FALL MEETING
In the City by the Bay

## Fall Meeting

### Session Highlights

San Francisco Dec. 7-11, 1981

#### Geomagnetism and Paleomagnetism

*Magnetite Biomineralization by Living Organisms (Th, PM)*

Join this special session on frontier research in biomagnetism, and explore the interaction of living organisms with the geomagnetic field. Topics include the search for ferromagnetic minerals in bacteria, butterflies, green sea turtles, and dolphins. The session will focus on how organisms synthesize magnetite and the possibility of a magnetic sense in animals. Recent developments concerning electromagnetic effects on cancer are also on the program.

#### Hydrology

*Impact of Richards' Equation Banquet*

The special session, Impact of Richards' Equation, is scheduled for Tuesday, December 8 at the Holiday Inn. There will be a luncheon banquet at noon. Don Nielsen will speak on Future Directions of Richards' Equations. Please send a check payable, in the amount of $8.50, to T. N. Narasimhan, Earth Sciences Division, Lawrence Berkeley Lab, Berkeley, CA 94720. Reserve Now! For more information call 415-486-5655.

#### Planetology

*Satellites of Jupiter and Saturn (W, AM)*

Surfaces and interiors of outer-planet satellites, with emphasis on processes that modify surfaces. Several of the papers treat cratering, crater relaxation, and tectonics on icy bodies.

*Outer Planets: Atmospheres, Ionospheres, and Rings (W, AM)*

The first three papers consider transient phenomena (braids, kinks, spokes, etc.) in and dynamics of ring systems. The remainder of the session is devoted to atmospheric states and processes, including flow patterns, emission, lightning, and chemistry.

*Early Solar System and Primitives (W, PM)*

This session includes papers on preplanetary disk conditions, then moves to meteorites and comets.

*Microwave Observations of the Planets (W, PM)*

A session on active and passive methods of studying planetary surfaces and atmospheres. Both earth-based and spacecraft experiments will be represented. New results as well as brief reviews of each subdiscipline will be included.

*Terrestrial Planets: Atmospheres and Ionospheres (Th, PM)*

Primarily a session on Venus atmospheric phenomena from the planet's surface to its interaction with the solar wind. Several papers discuss ionospheric models based on Pioneer Venus observations.

*Terrestrial Planets: Surfaces and Interiors (Th, PM)*

This session includes papers on gravity and differentiation of Venus and the evolution and temperature of the moon. A later paper discusses an early lunar core-dynamo magnetic field. The session concludes with presentations on cratering studies and on morphology, dynamics, and control of sand dunes.

#### Solar-Planetary Relationships

The Section of Solar-Planetary Relationships will sponsor several noteworthy sessions at the fall meeting. Special all-day sessions on Monday (SS) and Friday (SM) will feature the NASA Solar-Terrestrial Theory Program (STTP). The Monday papers are invited oral presentations by the STTP principal investigators. The Friday papers are contributed poster presentations by the STTP investigators and others in the field of space plasma theory. A special all-day session on Wednesday (SM) will feature invited and contributed talks on laboratory and space experiments designed to elucidate magnetospheric and ionospheric processes. A long session on Wednesday morning (SM) will highlight preliminary results from the Dynamics Explorer spacecraft launched this past August. Contributed sessions on aurora and substorms (M, AM/Th, AM) and on waves, instabilities, and turbulence in space plasmas (T, AM/Th, PM) will feature oral presentations early in the week and poster presentations on Thursday. The spectacular success of the poster sessions at Hurricane Hotel has earned us use of the El Dorado Room of the Jack Tar for this purpose at San Francisco. Attendees of the poster sessions on Thursday and Friday (SM) will find a gold mine of information there. Special sessions on the Magnetospheres of Jupiter and Saturn (SM) will be held Wednesday afternoon (contributed papers) and Thursday morning (invited papers) so as not to conflict with Planetology's special session on Voyager 2 results. The invited speakers on the magnetospheres of Jupiter and Saturn will each be given a full half hour (plus discussion time) on Thursday morning to review their respective topics from an impartial perspective.

#### Volcanology, Geochemistry, and Petrology

*Magma Energy (M, AM)*

Molten bodies of rock within 10 km of the surface are a potential source of energy. In the U.S. this source may exceed the annual energy consumption by 3 to 4 orders of magnitude. DOE's Magma Energy Research Project has concluded that extraction of energy from this source is scientifically feasible. This session will summarize the findings of the project, including drilling technology, energy extraction methods, and problems associated with operations in this unique environment.

*Hawaiian Volcanism (T, PM)*

Hawaii is best known for its two most active volcanos, Kilauea and Mauna Loa. The papers in this session focus on Kilauea Volcano, which erupts every few years. Included are the results of recent geochemical, geophysical, and geodetic monitoring of Kilauea as well as findings from recent drilling into the Kilauea Iki lava lake formed in 1959.

*Chemical and Convective Stratification of the Mantle (W, AM)*

It is the consensus of earth scientists that convection occurs in the mantle, but little is known about the vertical dimensions of the presumed mantle flow. The papers in this pair of sessions will present the geophysical and petrologic evidence for stratification and chemical variations in the mantle, explore the constraints on convection parameters placed by studies of subduction zones, and discuss theoretical aspects of mantle convection models.

*Geology of Loihi Seamount (Th, PM)*

Loihi Seamount, which lies 30 km southeast of the island of Hawaii, is probably the newest volcano in the Hawaiian-Emperor chain. The results of recent, closely coordinated geophysical, photographic, petrologic, chemical, and isotopic studies will be presented in this special session. The findings include data that may require significant modifications to the traditional petrogenetic model for Hawaiian volcanos.

*Explosive Volcanism: Inception, Evolution, and Hazards (Th, F)*

The catastrophic, explosive eruption of a volcano is one of nature's most spectacular displays. In order to provide a catalyst for additional research into the origin, mechanisms, and consequences of such eruptions the Geophysics Study Committee of the National Research Council has convened a Panel on Explosive Volcanism. The results of the panel's studies will be contained in two special sessions of invited papers that will explore explosive volcanism and the relations between tectonic and volcanic processes. The invited papers will be followed by two sessions of contributed papers on explosive volcanism in the Cascades and other volcanos in the western hemisphere.

*Island Arcs and Ophiolites (F)*

Two special sessions—Petrogenesis of Igneous Rocks in Intraoceanic Island Arcs and Ophiolites and Petrogenesis in Island Arcs—will focus on the relations between subduction and volcanism in the island arc tectonic setting. Included are petrologic and chemical studies of representative ophiolite sections and geochemical investigations of volcanic rocks from island arcs near active subduction zones.



## A Chapman Conference on Subsurface Water Contributions to Streamflow

A Chapman Conference on Subsurface Water Contributions to Streamflow was held October 5–9, 1980, at the New England Center for Continuing Education in Durham, N.H.

The purpose of the conference was to bring together an interdisciplinary group of scientists and engineers who are actively engaged in research on the processes by which water from atmospheric precipitation moves into and through the subsurface on the way to becoming streamflow. Subsurface here means everything from the uppermost leaf or litter layer just beneath land surface down to and including the underlying saturated zone. This approach also requires consideration of evapotranspiration and capillary forces, which remove water from within the flow system either permanently or temporarily.

The discussions and papers dealt with a series of major topics, each of which was introduced by an invited speaker. The boundaries between topics proved fluid to say the least, However, and, in fact, over one half of the participants were most interested in what has come to be called hillslope hydrology. (That is, the emphasis was on processes at the 'grass-roots' level.) For these reasons, the presentations are generally given in chronological order instead of attempting to categorize them exactly by topic.

The conference began with a discussion by D. D. Huff (Oak Ridge) of the latest progress with PROSPER II, a model for atmosphere-soil-plant-water flow. J. L. Nieber (Texas A&M) pointed out the importance of capillary hysteresis in saturated-unsaturated flow by comparing the results of finite element simulation and laboratory modeling for flow in a sloping slab. A. L. O'Brien (Lowell) showed from groundwater level and stream hydrograph relationships that as much as 90% of flow from a wetland could come from groundwater.

A most provocative presentation was given by D. Hillel (Massachusetts) on evapotranspiration with emphasis on the complexities of both soil evaporation and plant transpiration. Commonly held assumptions about uniformity of evapotranspiration over broad areas regardless of plant or soil type are suspect, and the widely used idea of potential evapotranspiration is hard to define in actual practice. F. I. Morton (Environment Canada) discussed his development of the complementary relationship between actual and potential evapotranspiration through use of routinely obtained climatologic data. Ben Sill (Clemson) pointed out the bounds imposed by atmospheric stability on evaporation prediction by the bulk aerodynamic method. He presented a method for incorporating this into the current evaporation equation where it is commonly ignored.

H. J. Morel-Seytoux (Colorado State) demonstrated the value of analytical solutions in considering infiltration through the unsaturated zone. J. B. Urban and W. J. Gburek (SEA-AR) are attempting to model baseflow in a New England watershed by considering the physical control exerted by saturated seepage in a fairly shallow soil and fracture zone overlying impermeable bedrock. They obtained recessions they consider to be characteristic of the subwatersheds. Recent results of work with a variable source area simulator, VASA, were given by P. Y. Bernier and L. J. Lefkoff (Georgia). This model will also be linked to PROSPER II, which was discussed above.

D. D. Fritton (Pennsylvania State) highlighted the difficulties in quantitatively describing porous media flow properties in the unsaturated zone except for a homogeneous medium. He emphasized the unsaturated hydraulic conductivity function and some ways of measuring it. This was followed by L. K. Kuiper (USGS) who considered the problem of head decline in a confined aquifer due to vertical water movement in an overlying saturated-unsaturated confining bed. D. K. Babu (Princeton) presented some analytical results describing the response of the capillary zone above a water table to recharge. Specifically, Babu's results indicate the water table can rise very quickly.

A definitive survey of the need for monitoring and related problems with instrumentation for hillslope processes was given by M. G. Anderson (Bristol). Good data are needed, and broad generalizations are to be avoided, if valid inferences are to be made. M. G. Sklash (Windsor) gave the results for environmental isotopes studies that show a major portion of storm runoff in a stream in a humid region is likely to come mainly from groundwater close to the stream. A groundwater ridging theory has been developed to explain the phenomenon. K. Beven (Virginia) introduced his preliminary results in using the kinematic wave approximation for predicting subsurface stormflow hydrographs. The complex problem of what goes on at the interface between the unsaturated and the saturated zones was discussed by T. N. Narasimhan (Lawrence Berkeley Laboratory). He pointed out that the two zones should be considered in a uniform fashion instead of being arbitrarily separated.

T. D. Steele (Woodward-Clyde) reviewed current work on chemical aspects of groundwater-surface water interactions mainly by use of case studies. L. R. Ahuja (SEA-AR) presented the results of studies on interflow in sloping soils and how chemicals may be transported through this region. D. F. Ryan (Dartmouth) gave the preliminary findings of modeling chemical movement in stream flow for a New England watershed. He observed that simple dilution models may describe average chemistry reasonably well but that they do not describe the process in a realistic way. H. J. Simpson (Lamont-Doherty Geological Observatory) showed the value of radon 222 measurement for tracing groundwater input to streamflow.

The invited speaker for water management was unable to attend; however, H. J. Morel-Seytoux (Colorado State) proved a willing and able volunteer. He emphasized the value of analytical response functions for stream-aquifer systems instead of numerical models because of simplicity and decreased computer time. D. N. Folkman and D. T. Pederson (Nebraska) discussed the problems of describing stream-aquifer interactions when flowing wells and pumping irrigation wells are present.

J. A. Lynch (Pennsylvania State) and E. S. Corbett (U.S. Forest Service) gave presentations on the role of antecedent soil moisture and the stormflow generation process as observed in an instrumented experimental watershed where artificial rainfall was applied in various patterns and at various rates.

J. DeVries (British Columbia) and M. G. Utting (Hart, Crowser and Associates) discussed the stormflow generation processes on a steep coastal watershed. The apparent non-Darcian nature of subsurface stormflow was of particular interest with logs, root holes, and the like serving as flow conduits. Computer simulations of hillslope runoff was covered by R. A. Freeze (British Columbia). He also demonstrated that realistic patterns could be obtained by treating hydraulic properties as stochastic variables.

During the conference, poster sessions were given with F. I. Morton (Environment Canada) further illustrating his use of the complementary relationship between actual and potential evapotranspiration. K. Beven and coworkers at Virginia presented their ideas and preliminary results for a study of the impact of acid precipitation on catchments in Shenandoah National Park. L. R. Ahuja and J. W. Naney (SEA-AR) demonstrated a method of soil water characterization of two watersheds under different management schemes. R. K. Wright (McGill) gave the results of a detailed study of the water balance in a small subarctic watershed. Also, during the conference M. G. Sklash (Waterloo) gave an impromptu talk on the use of environmental isotopes for investigating storm runoff, and D. R. Lee (Atomic Energy of Canada) discussed some of his work with groundwater-lake interactions.

The conference finished with a panel discussion on research needs by T. A. Prickett (Camp, Dresser and McKee), M. E. Moss (U.S. Geological Survey), and D. Hillel (Massachusetts) with one interesting theme being the need to use analytical solutions where possible and to avoid elaborate numerical solutions where they are not warranted. J. F. Daniel (U.S. Geological Survey) then gave an overview of the Conference as a whole. He pointed out that there was an interesting geographic bias between those on the west coast of the United States and Canada, east coast of the United States, and England who preferred nonlinear approaches and those in the central United States and Canada who preferred linear approaches, which seemed to carry over into their views of the importance of the capillary fringe. He indicated that we should let the physics and mathematics define the flow system and not get hung up in terminology. He also noted a tendency for theoretical overkill to what appeared to be rather practical problems and a tendency to neglect the literature.

The conference was cosponsored by the University of New Hampshire; the United States Department of Agriculture, Science and Education Administration—Agricultural Research (SEA-AR); the United States Department of Agriculture, Forest Service—Northeastern Forest Experiment Station; and the American Water Resources Association. The convener was Francis R. Hall, University of New Hampshire. Financial support from SEA-AR provided for a distinguished invited speaker from England and assisted in the attendance of a graduate student. The U.S. Forest Service supported the abstracts volume, and AGU paid transportation for a graduate student. This help is deeply appreciated.

Supplement (abstracts) available with entire meeting report on microfiche. Order from American Geophysical Union, 2000 Florida Ave., N.W., Washington, D. C. 20009. Document E81-007; $1.00. Payment must accompany order.



AGU FALL MEETING

### Job Center

AGU will again have a Job Center at the Fall Meeting in San Francisco. Employers should bring job descriptions for posting. Candidates should bring copies of their resumes. Sign up and interviewing will be in the Holiday Inn. See November 10 issue of *Eos* or program for details.

### Special Session on Geophysical Education

An open discussion on special educational needs of the various disciplines in geophysics by AGU Section Officers and those with an interest in the education of geophysicists. For further details contact C. T. Russell at 213/825-3188.

### AGU Women's Subcommittee Open Meeting and Panel

*Wednesday, December 9—5:30–7:00 P.M.*
*Jack Tar Hotel*

See the program information section of the November 10 *Eos* for details on the program

# GAP

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## Aeronomy

0410 Absorption and scattering of radiation
IDENTIFICATION OF ACETYLENE ($C_2H_2$) IN INFRARED ATMOSPHERIC ABSORPTION SPECTRA
[illegible] (Department of Physics, University of Denver, Denver, Colorado 80208), F.J. Murcray, R.D. Blatherwick, J.J. Kosters, F.H. Murcray, and R.J. Cicerone.
Infrared atmospheric absorption spectra at ~0.02 $cm^{-1}$ resolution obtained during a balloon flight on 3/23/81 show absorption features attributable to $C_2H_2$. These features are used to derive a preliminary mixing ratio of [illegible] ppbv near [illegible] km. This mixing ratio falls into the range of values [illegible] for upper tropospheric $C_2H_2$ in [illegible] measured previously in samples collected by other researchers.
J. Geophys. Res., Green, Paper 1C1573

0410 Absorption and scattering of radiation
[illegible]
[illegible] (Center for [illegible], Cambridge, Massachusetts 02138), [illegible]
[illegible] J. Geophys. Res., Blue, Paper 1A1596

0430 Composition (atomic or molecular)
MESOSPHERIC WATER VAPOR
S. Deguchi and D.O. Muhleman (Div. of Geological and Planetary Sciences, Calif. Institute of Technology, Pasadena, California 91125)
Water vapor in the earth's mesosphere has been observed at the frequency of 22.235 Ghz as an absorption against the sun utilizing a ground-based radio telescope. The $H_2O$ mixing ratio of 4.1 ± 1 ppm is obtained in the height 40–70 km for a constant distribution model. The data are equally well represented by a photochemical model of Crutzen (1974) which was scaled by a factor of 0.93 yielding a peak mixing ratio of 6 ± 1 ppm at 55 km. These results are 3 day averages during November 1979 where the averaging periods cover the about ±4 hours of the sun's transit of our meridian. The measurements are insensitive to $H_2O$ above 70 km where the absorption is very weak. We cannot estimate the mixing ratios below 50 km since the pressure broadening in the line exceeds the bandwidth of our spectrometer at the lower altitudes. (Water vapor, mesosphere, radio telescope).
J. Geophys. Res., Green, Paper 1C1600

0430 Composition (Atomic or molecular)
LONG TERM VARIATIONS IN ATOMIC NITROGEN DENSITIES
M. J. Engebretson (Department of Physics, Augsburg College, Minneapolis, Minnesota 55454) and J. B. Nygren
Thermospheric densities of atomic and molecular nitrogen were measured from February 1976 through December 1978 by the Open-Source Neutral-Mass Spectrometer (OSS) on the equatorial Atmosphere Explorer-E satellite. During this period a significant increase in N densities was observed at altitudes of 250 km and above. We believe the increases can be explained by increased production of N due to enhanced solar extreme ultraviolet radiation but not by a simple rise in thermospheric temperature. Empirical modeling of N densities at 250 and 375 km using stepwise regression techniques indicates that the increased solar EUV fluxes in the 800–1800 Å range are sufficient to account for the observed rise in N densities at 250 km from June 1976 to June 1977, and are the dominant factor in the density increase of a factor of 5 observed at 375 km altitude from June 1976 to late 1978.
J. Geophys. Res., Blue, Paper 1A1570

0430 Composition (atomic or molecular)
THE ROLE OF METASTABLE SPECIES IN THE THERMOSPHERE
M. R. Torr (Center for Atmospheric and Space Sciences, UMC 34 Utah State University, Logan, Utah 84322) D. G. Torr
Longlived or metastable excited states of various atoms and molecules in the thermosphere provide reservoirs for the temporary storage of a considerable portion of the solar EUV photon energy deposited in the thermosphere. These species permit the redistribution of energy via collision processes yielding kinetic or vibrational heating, ion formation, the formation of other metastable species and the non-local deposition of the energy, as opposed to spontaneous radiative decay. While thermospheric species such as $O(^1S)$ have been studied for decades, and indeed provided the first evidence for forbidden transitions, others have a relatively short history. The body of information concerning metastable constituents of relevance to the thermosphere has grown considerably over the past decade, to the point where it is timely to consider the status and future needs of research in this area. In this paper we review the developments leading to the current photochemical picture of $O(^1D)$, $O(^1S)$, $O^+(^2D)$, $O^+(^2P)$, $N(^2D)$, $N(^2P)$, $N^+(^1S)$, $N^+(^1D)$, $N_2(A^3\Sigma_u^+)$, $NO^+(a^3\Sigma)$, $O_2^+(a^4\pi_u)$, and the vibrationally excited states of $N_2$, $O_2$, $O_2^+$, and $N_2^+$. Because a primary significance of these constituents is their role in the thermospheric energy budget, we quantify the major metastable channels by which solar EUV radiation is redistributed in the thermosphere. A few of the major highlights are: a major fraction of the kinetic heating of the thermosphere takes place via the single constituent $O(^1D)$; $N_2(A^3\Sigma_u^+)$ and vibrationally excited $N_2$ also are important heating channels; $O^+(^2D)$ is a primary factor in determining the thermospheric ionic composition; species such as $O^+(^2P)$ and $N^+(^1S)$ provide valuable ways in which to optically determine the concentrations of certain major species, measurement of emissions from the former yield the atomic concentration as well as the ion drift speed, and measurement of emissions from the latter provide the concentration of $N_2$; $N(^2D)$ remains a major source of NO; and a recent finding is that vibrationally excited $N_2^+$ plays a vital role in converting $N_2^+$ into $O^+$.
Rev. Geophys. Space Phys., Paper 1R1541

0460 Tides, waves and winds
A DISPERSION FORMULA FOR ANALYSING "MODAL INTERFERENCE" AMONG GUIDED AND FREE GRAVITY-WAVE MODES AND OTHER PHENOMENA IN A REALISTIC ATMOSPHERE
T.F. Tuan (Physics Dept., University of Cincinnati, Cincinnati, Ohio 45221) and D. Tadic
Gravity waves are known to propagate in the continuous as well as the partially and fully guided modes. Through the development of a dispersion formula, we will show that these three modes can "interfere" among themselves and that one important consequence of such "interference" is that the guidance of a large number of partially guided modes can be destroyed. The simple formula for the effective attenuation distance, $-1/Imk_{xn}$ for each complex partially guided mode $k_{xn}$ (where $k_x$ is the horizontal wave vector), is no longer valid when there is heavy "interference" or "modal overlap." A simple criterion will be developed to distinguish those modes which remain observable from those which exist physically only as part of the general background.
We will also show that the presence of an explicit gravity-wave source can only selectively or simultaneously excite those modes which are observable and that the other modes remain as part of the background, unaffected by the source. The dispersion formula also shows that a discrete mode should be described by two parameters. One is the usual modal position $k_{xn}$, while the other is the "weight" which varies with different modes. There is also the possible existence of yet another form of guided mode which we will call the virtually guided mode and which possesses characteristics quite different from the other guided modes.
J. Geophys. Res., Blue, Paper 1A1509

0499 General
THE DIURNAL VARIATION OF ATMOSPHERIC SODIUM
B. R. Clemesha (Instituto de Pesquisas Espaciais, C.P. 515, São José dos Campos, S.P. Brazil), D. M. Simonich, P. P. Batista and V. W. J. H. Kirchhoff
Continuous measurements of the vertical distribution of atmospheric sodium, made over a number of complete diurnal cycles, show the existence of strong semidiurnal oscillations in total abundance and height. The amplitude of the abundance variation, about 15% of the mean, is about twice that predicted for the 2,2 mode of the semi-diurnal tide, and its phase, with maxima at 0400 and 1400 LT, is in good agreement with tidal theory. The vertical oscillation, with an amplitude of 2 km at a height of 100 km, is about 3 times the expected amplitude, and the measured vertical wavelength of 38 km is in good agreement with theory although the phase is not. A strong diurnal oscillation, observed only at heights below 82 km, is interpreted as being the result of photochemical reactions between sodium and other atmospheric constituents. The lack of any appreciable 24-hour component in the total abundance variation implies either a residence time for total sodium of more than 3 days, or source and sink functions whose diurnal variations, unless indentical, are very small. (Atmospheric sodium, tides).
J. Geophys. Res., Blue, Paper 1A1565

## Physical Properties of Rocks

6110 Elasticity, fracture, and flow
SHEAR FRACTURE ENERGY OF WESTERLY GRANITE FROM POST-FAILURE BEHAVIOR
T.-F. Wong (Department of Earth and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139 U.S.A.)
We consider in this paper the energetic relationship among four different types of measurements - evaluation of shear fracture energy from seismological data, rock mechanics study of post-failure behavior in triaxial compression, measurement of specific surface energy of minerals in a tensile mode, and SEM observation of stress-induced microstructures.
Shear fracture energy can be estimated from post-failure deformation data following an integration scheme recently suggested by Rice. Values so determined for Westerly granite at pressures up to 250 MPa and temperatures up to 700°C are of the order $10^4$ $Jm^{-2}$, which are about two orders of magnitude higher than the tensile values. Analysis of our data, together with previous room temperature post-failure data, show that the influence of temperature, pressure, and rock type can change the shear fracture energy by an order of magnitude.
Microcracking energy can be estimated by multiplying the stress-induced crack area (obtained by stereological technique) and the single crystal specific surface energy. Energy for the extension of microcracks resolvable under SEM can account for a major portion of the total energy input for pre-failure deformation. However, for post-failure deformation the former is smaller than the latter by at least an order of magnitude.
J. Geophys. Res., Red, Paper 1B1502

6110 Elasticity, fracture, and flow
STUDY OF A [illegible] SEISMIC [illegible]
Robert F. [illegible] (Department of Earth and Planetary Sciences, [illegible] Institute of Technology, [illegible]), [illegible] Turpening, [illegible]
[illegible]
J. Geophys. Res., [illegible]

6110 Elasticity, fracture, and flow
PARAMETRIC ANALYSES OF THE TRANSIENT METHOD OF MEASURING PERMEABILITY
Norman Lin (Lawrence Livermore National Laboratory, University of California, Livermore, CA 94550)
Analyses are made to compare the two approaches of using the transient method to determine permeability of rocks: the simplified version and the numerical version. The simplified version assumes that when the sample volume is much smaller than the reservoir volume the fluid storage in a rock sample can be neglected and the pressure decay in the upstream reservoir can be approximated by an exponential function of time. The numerical version uses finite difference method to solve the differential equation of pressure decay and matches the observed pressure decay with calculated curves. The pressure decay calculated by the numerical version is not generally a simple exponential function of time, as suggested by the simplified version. Our analyses show that the numerical version fits the observed data very well. The permeability value determined by the simplified version tends to be greater than that determined by the numerical version. The difference in apparent permeability between the two depends on many factors such as rock properties (porosity and compressibility), sample size, reservoir volumes, etc. A relative fluid storage is used to illustrate the difference of these two approaches. For a relative fluid storage of greater than 0.03 the difference in permeability between the two is more than 30%. For a system with a fluid storage of less than 0.01, these two versions agree with each other well.
J. Geophys. Res., Red, Paper 1B1499

6120 Equations of state
SHOCK COMPRESSION OF ARAGONITE AND IMPLICATIONS FOR THE EQUATION OF STATE OF CARBONATES
Joann Vizgirda and Thomas J. Ahrens (Seismological Laboratory, California Institute of Technology, Pasadena, California 91125)
Hugoniot equation of state and release adiabat results are presented for c-cut crystals of aragonite, the high pressure polymorph of calcite, shocked to pressures of up to 40 GPa. A Hugoniot elastic limit is observed at 3.1 ± 0.9 GPa and is similar to that of calcite, which, depending on orientation, ranges from 1.5 to 2.5 GPa. A phase transition, possibly displacive, occurs between 5.5 and 7.6 GPa. Above shock pressures of ~10 GPa, the aragonite and calcite Hugoniots are nearly coincident, suggesting transformation of both polymorphs to the same phase. Model calculations, attempting to characterize the high pressure $CaCO_3$ phase are presented. Aragonite release adiabats centered at pressures between 9 and 18 GPa indicate that states with apparent zero-pressure densities from 2.9 to 3.2 g/cc are achieved upon decompression from progressively greater shock pressures. Observed unloading paths from shock pressures above 17 GPa are significantly and consistently shallower (in a density-pressure plane) than those from lower pressures, and zero-pressure densities in 1% below that of the initial aragonite density are achieved upon unloading; these features suggest that vaporization is occurring upon unloading. According to continuum shock temperature and entropy calculations however, the minimum shock pressure for vaporization upon release for aragonite is 35 GPa, [illegible] significantly higher than the observed value.
J. Geophys. Res., Red, Paper 1B1480

6140 Magnetic and electrical properties
THE FIELD DEPENDENCE OF MAGNETIC BLOCKING TEMPERATURES: ANALOG TESTS USING CHEMICAL [illegible]
D.J. Dunlop (Geophysics Laboratory, Department of Physics, University of Toronto, Toronto, Canada M5S 1A7)
The field dependence of blocking temperatures $T_B$ and the temperature dependence of coercive force $H_c$ are shown to be analogous functions. [illegible]
J. Geophys. Res., Red, Paper 1B1495

6140 Magnetic and electrical properties
RELATION OF CERTAIN GEOMETRICAL FEATURES TO THE DIELECTRIC ANOMALY OF ROCKS
P.N. Sen (Schlumberger-Doll Research, P.O. Box 307, Ridgefield, CT 06877)
We show that the real part of the dielectric constant ε' of rocks at low frequencies can be anomalously high due to the presence of a small concentration of high aspect ratio particles. [illegible]
J. Geophys. Res., Red, Paper 1B1422

6145 General or miscellaneous
[illegible]
J. Geophys. Res., Red, Paper 1B1535

## Planetology

6510 Atmospheres of planets
TIME-DEPENDENT CALCULATIONS OF JUPITER'S IONOSPHERE
Y.H. Chen (Center for Radar Astronomy, Stanford University, Stanford, CA 94305)
Time-dependent calculations of the vertical distribution of protons in Jupiter's ionosphere show that the accumulation of protons produced from solar ionizing radiation overwhelms the loss to vibrationally excited molecular hydrogen even at vibrational temperatures as high as 1600°K. [illegible]
J. Geophys. Res., Blue, Paper 1A1114

6510 Atmospheres of Planets
HOLES IN THE NIGHTSIDE IONOSPHERE OF VENUS
L. H. Brace (NASA/Goddard Space Flight Center, Laboratory for Planetary Atmospheres, Greenbelt, MD 20771) R. F. Theis, H. G. Mayr, S. A. Curtis, J. G. Luhmann [illegible]
Measurements of electron density and temperature by the Pioneer Venus Orbiter Electron Temperature Probe have been employed to examine the characteristics and morphology of ionospheric holes in the nightside ionosphere of Venus. [illegible]
J. Geophys. Res., Blue, Paper 1A1476

6545 Interiors of Planets
ELASTIC THICKNESS OF THE VENUS LITHOSPHERE ESTIMATED FROM TOPOGRAPHY AND GRAVITY
A. Cazenave and E. Dominh (Groupe de Recherches de Géodésie Spatiale, Toulouse, France)
The very close correlation observed on Venus between topography and gravity on a regional scale is clearly related to the isostatic compensation of the topographic loads. Observed gravity anomalies over topographic features of moderate lateral extent, located in the equatorial region [illegible]
J. Geophys. Res., Red, Paper 1B1310

6570 Surface of moon
INELASTIC NEUTRON SCATTER [illegible] FROM ORBITAL GAMMA-RAY DATA
P.A. Davis (U.S. Geological Survey, Flagstaff, Arizona) and [illegible] Bielefeld
[illegible]
J. Geophys. Res., Red, Paper 1B1422

6575 Surface of planets
SEQUENTIAL DEVELOPMENT OF GROOVED TERRAIN AND POLYGONS ON GANYMEDE
Matthew P. Golombek (Lunar and Planetary Institute, 3303 NASA Rd. 1, Houston, Texas, 77058), M. Lee Allison
Grooves on Ganymede have been interpreted as fractures [illegible]
Geophys. Res. Lett., Paper 1L1483

6575 Surface of Planets
A SCHEMATIC MODEL OF CRATER MODIFICATION BY GRAVITY
H. J. Melosh (Earth and Space Sciences Dept., SUNY Stony Brook, Stony Brook, N.Y. 11794)
[illegible]
J. Geophys. Res., Red, Paper 1B1269

6575 Surface of Planets
MARS RESIDUAL NORTH POLAR CAP: EARTH-BASED SPECTROSCOPIC CONFIRMATION OF WATER ICE AS A MAJOR CONSTITUENT AND EVIDENCE FOR HYDRATED MINERALS
R.N. Clark (Planetary Geosciences, Hawaii Inst. of Geophysics, Univ. of Hawaii, 2525 Correa Road, Honolulu, HI 96822) T.B. McCord
[illegible]
J. Geophys. Res., Red, Paper 1B1101

6590 Instruments and techniques
RADIOMETRIC PERFORMANCE OF THE VOYAGER CAMERAS
G.E. Danielson (M/S 170-25, California Institute of Technology, Pasadena, CA 91125) P.N. Kupferman, T.V. Johnson, L.A. Soderblom
[illegible]
J. Geophys. Res., Blue, Paper 1A0900

6599 Planetology, general
IO'S HOT PLASMA TORUS - A SYNOPTIC VIEW FROM VOYAGER
B.R. Sandel (Earth and Space Sciences Institute, 3625 E. Ajo Way, Tucson, Arizona 85713) A.L. Broadfoot
A study of the morphology of Io's hot plasma torus has encompassed hundreds of Voyager UVS measurements of torus intensity. The long-term average state of the torus can be characterized by an axial asymmetry in the brightness of the prominent SIII 685 Å feature, manifested as an enhancement in brightness whose peak is fixed near 1900 local time. No long-term correlation of brightness with magnetic longitude is present. On time scales of a few Jupiter rotations, the torus can differ markedly from its average axial asymmetry, and its brightness is correlated with magnetic longitude for short times.
J. Geophys. Res., Blue, Paper 1A1434

## Seismology

6950 Seismic sources
RECENT LARGE EARTHQUAKES ALONG THE MIDDLE AMERICAN TRENCH AND THEIR IMPLICATIONS FOR THE SUBDUCTION PROCESS
E. P. Chael, (Seismological Laboratory, California Institute of Technology, Pasadena, California 91125) G. S. Stewart
Several large shallow earthquakes ($M_s$ > 7.0) have occurred along the Middle American Trench since the installation of the WWSSN network. Included are the 1965, 1968, and 1978 Oaxaca events, the 1970 Chiapas event, the 1973 Colima event and the 1979 Petatlan event. These earthquakes have been studied in an attempt to identify similarities and differences between them that may lead to a better understanding of fracture and subduction processes. The events have seismic moments ranging from $1.0 \times 10^{27}$ dyne-cm for the 1968 event to $3.2 \times 10^{27}$ dyne-cm for the 1978 event. All events are of predominantly thrust type, consistent with subduction to the northeast of the Cocos plate. Body waves for the 1965, 1968, 1978 and 1979 events along the trench indicate rather simple faulting processes. These events all had focal depths of 15 to 20 km and stress drops on the order of 10 bars. The 1970 and 1973 events, the eastern- and western-most, respectively, of the events studied here are located close to triple junctions for the Cocos-N. America-Caribbean plates (1970) and the Cocos-N. America-Rivera plates (1973). These two events generated more complex body waves than the Oaxaca and Petatlan quakes. This source complexity may have been related to the more complicated tectonics near the 1970 and 1973 epicenters. This may offer a new perspective to viewing source complexity in relation to subduction zones. (Mexico, Middle American Trench, Oaxaca, Cocos plate, subduction, complexity, triple junctions).
J. Geophys. Res., Red, Paper 1B1585

6950 Seismic Sources
THE EXCITATION OF LONG PERIOD SEISMIC WAVES BY A SOURCE SPANNING A STRUCTURAL DISCONTINUITY
J. H. Woodhouse (Department of Geological Sciences, Hoffman Laboratory, Harvard University, Cambridge, MA 02138)
Simple theoretical results are obtained for the excitation of seismic waves by an indigenous seismic source in the case that the source volume is intersected by a structural discontinuity. In the long wavelength approximation the seismic radiation is identical to that of a point source placed on one side of the discontinuity or of a different point source placed on the other side. The moment tensors of these two equivalent sources are related by a specific linear transformation and may differ appreciably both in magnitude and geometry. Either of these sources could be obtained by linear inversion of seismic data but the physical interpretation is more complicated than in the usual case. A source which involved no volume change would, for example, yield an isotropic component if, during inversion, it were assumed to lie on the wrong side of the discontinuity. The problem of determining the true moment tensor of the source is indeterminate unless further assumptions are made about the stress glut distribution; one way to resolve this indeterminancy is to assume proportionality between the integrated stress glut on each side of the discontinuity.
Geophys. Res. Lett., Paper 1L1312

6970 Structure of the crust and upper mantle
REASSESSMENT OF A REPORTED S-DELAY UNDER TRINDADE
H. C. Nataf (Seismological Laboratory, California Institute of Technology, Pasadena, California, 91125, U.S.A.) T. Lay, D. L. Anderson and E. A. Okal
We present a correction to a paper by Okal and Anderson (1975) about multiple ScS travel-time anomalies. We have reanalyzed data for $ScS_2$ surface bounces in the South Atlantic Ocean. From these data an $ScS_2$-S residual of 23.6 seconds was found by Okal and Anderson (1975). This corresponded to an $ScS_2$ surface bounce point under Trindade Island and was inferred to be due to very slow upper mantle associated with the Trindade hot spot. The analysis we present here invalidates this conclusion. The nature of the upper mantle under Trindade is an open issue. (S-delay, Trindade, hot spot).
Geophys. Res. Lett., Paper 1L1372

6970 Seismology (Structure of the crust and upper mantle
UPPER CRUSTAL VELOCITY STRUCTURE IN THE ROSE AREA OF THE EAST PACIFIC RISE
J.I. Ewing (Department of Geology & Geophysics, Woods Hole Oceanographic Institution, Woods Hole, MA 02543), G.M. Purdy
We describe a method to constrain the seismic velocity structure of the upper 500-800m of young oceanic crust. Conventional interpretations of seismic refraction profiles provide little or no information concerning this shallowmost crust. The method described here requires the assumption of a linear velocity gradient and utilizes measured values of range, travel time and slowness of the observed refracted waves. Results are reported from several refraction profiles that sample crust between 0m.y. and 4m.y. in age on the flanks of the East Pacific Rise at 12°N. These data give an average gradient in the uppermost 800M of the crust of $3.6s^{-1}$ and a velocity at the seafloor of 2.5km/s. Ray path and travel time modeling show that the refracted waves sampling the uppermost part of the crust are effectively masked by reflections from the seafloor.
J. Geophys. Res., Red, Paper 1B1522

6970 Structure of the crust and upper mantle
FINE STRUCTURE OF THE DIPPING SEISMIC ZONE AND SUBDUCTION MECHANICS IN THE SHUMAGIN ISLANDS, ALASKA
M. Reyners, and K. H. Coles (Lamont-Doherty Geological Observatory and Department of Geological Sciences of Columbia University, Palisades, NY 10964)
Microearthquake data from a permanent, telemetered array have been used to elucidate the structure and tectonics of the subduction zone in the Shumagin Islands, Alaska. The shallow microseismicity is characterized by active interplate thrusting in the 25-45 km depth range. Arcward of this interplate activity, microearthquakes in the overlying plate have a strike-slip mechanism. The near-horizontal P-axis of this mechanism is oriented in the direction of plate convergence, suggesting that the plate interface at shallow depths is currently efficiently coupled. Below 45 km depth, the dipping seismic zone appears to be double-planed. The upper plane dips at 32° from 45 to 100 km depth, where it exhibits a knee-like bend below the volcanic front. The lower plane begins at about 65 km depth, where it is separated from the upper plane by some 25 km, and appears to converge with the upper plane at about 120 km depth. The inferred geometry of the plate interface suggests that the double-planed portion of the dipping seismic zone is a product of elastic unbending of the subducted plate. A composite fault-plane solution for events in the upper plane indicates, however, that down-dip tension is currently present, rather than the down-dip compression that would be expected from unbending. It is proposed that, because of locking of the plate interface at shallower depths, slab pull is currently overprinting the unbending stresses which predominate at times when the plates are unlocked. This model is consistent with previous interpretations that there is a high probability of a great earthquake in the Shumagin Islands seismic gap within the next decade or two. (Subduction, double-planed seismic zones, composite focal mechanisms).
J. Geophys. Res., Red, Paper 1B1543

6970 Structure of the crust and upper mantle
THE VELOCITY STRUCTURE OF THE PAMIR-HINDU KUSH REGION: POSSIBLE EVIDENCE OF SUBDUCTED CRUST
S.W. Roecker (Department of Earth & Planetary Sciences, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139 U.S.A.)
The arrival times of compressional (P) and shear (S) waves from approximately 580 microearthquakes recorded by a temporary array in the Pamir-Hindu Kush region in central Asia are used to deduce one- and three-dimensional velocity structures of this region. The results for one-dimensional structures imply that the Moho is at 70 ± 5 kilometers depth. Also, there is a velocity reversal near 160 kilometers depth, which is inferred to be the beginning of the low velocity zone. This reversal continues to depths of approximately 230 kilometers. Below 230 kilometers, velocities are somewhat higher than those of normal mantle at similar depths (9.3 km/sec vs. 8.4 km/sec for P waves). The outstanding feature of the results for three-dimensional velocity structures is a broad (>40 kilometers), centrally located region with 8% to 10% lower velocities than those in the surrounding regions. This low velocity region envelopes the seismic zone at depths between 70 and 150 kilometers. The region may actually extend beyond these depths, but the results for shallower and deeper structure lack sufficient resolution to decide. Several tests, using both hypothetical and real data, were performed to estimate the reliability of the three-dimensional solutions. The results of these tests suggest that the inferred velocities are reasonably accurate representations of the average velocities in the blocks, although one must be cautious of the effects of averaging in interpreting the solution. The low velocity region is inferred to be a manifestation of substantial quantities of subducted continental crust. Therefore, while subduction has occurred in the Pamir-Hindu Kush, the results of the three-dimensional inversions suggest that continental, rather than only oceanic, lithosphere has been subducted to depths of at least 150 kilometers. (Velocity, Hindu kush).
J. Geophys. Res., Red, Paper 1B1529

6980 Surface Waves
MOMENT TENSOR INVERSION OF LONG PERIOD RAYLEIGH WAVES : A NEW APPROACH
B.A. Romanowicz (Department of Earth and Planetary Sciences, M.I.T., Cambridge, Mass., 02139)
A modification of the moment tensor inversion method is presented, which significantly improves depth and source mechanism resolution from complex spectra of Rayleigh waves in the period range 30-90 sec. The procedure consists of two steps: first the spectra are separated at each frequency into a depth sensitive and a depth insensitive component. The latter consists of biases and errors and is discarded. The former is then used alone to invert for depth and source mechanism. Each of the five resolvable components of the moment tensor can be monitored separately as a function of depth. The depth is best determined from the residuals curves corresponding to the dominant components, which depend on the source mechanism. Several examples of application are given. It appears that phase velocities determined using one larger event with a well constrained mechanism and depth from body waves can be successfully used as path corrections in a source region around it, 500-1000 km in radius. For other events in the region, depth can now be constrained to within ± 5 km, and source mechanism, to within ± 5° in each of the three angles : strike, dip and slip. On the other hand, if only a rough estimate of depth and source mechanism is needed, regionalized phase velocities can now be used for path corrections. Finally, it is shown that, for certain depth ranges and certain mechanisms, the choice of the periods used in the inversions can be crucial in avoiding biases in depth determination. ( Rayleigh waves, inversion, source parameters, depth).
J. Geophys. Res., Red, Paper 1B1450

## Solar Physics, Astrophysics, and Astronomy

7710 Corona
POSSIBLE EVIDENCE FOR CORONAL ALFVÉN WAVES
J. V. Hollweg (Department of Physics, Space Science Center, University of New Hampshire, Durham, NH 03824) M. K. Bird, H. Volland, P. Edenhofer, C.T. Stelzried and B.L. Seidel
The 2.29 GHz S-band carrier signals of the two Helios spacecraft are used to probe the magnetic and density structures of the solar corona inside 0.05AU. In this paper we analyse the observed fluctuations of the electron content and Faraday rotation. A simple statistical ray analysis is employed. We conclude: 1. The observed Faraday rotation fluctuations cannot be solely due to electron density fluctuations in the corona unless the coronal magnetic field is some 5 times stronger than suggested by current estimates. 2. The observed Faraday rotation fluctuations are consistent with the hypothesis that the sun radiates Alfvén waves with sufficient energies to heat and accelerate high-speed solar wind streams.
J. Geophys. Res., Blue, Paper 1A1402

7710 Corona
MAGNETOSTATIC ATMOSPHERES IN A SPHERICAL GEOMETRY AND THEIR APPLICATION TO THE SOLAR CORONA
J. R. Hundhausen (Colorado School of Mines, Dept. of Math., Golden, Colorado) A. J. Hundhausen, E. G. Zweibel.
The formalism for deriving "two dimensional" magnetostatic equilibria is extended to spherical coordinates and applied to magnetic fields that are functions of radius and polar angle. A family of analytic solutions is readily found. The basic properties of these solutions are displayed for a dipole magnetic field at the base of the atmosphere and for physical parameters appropriate to the solar corona. Variation of the concentration of plasma at the "magnetic equator" illustrates the distortion of a simple dipole magnetic field by the electric currents required to maintain force balance in the presence of the imposed pressure gradients in the polar direction. The deviation of the magnetostatic field lines from the simple dipole configuration depends on the parameter

$$\frac{P_{eq} - P_{pole}}{B_0^2 / 8\pi}$$

where $P_{eq}$ and $P_{pole}$ are the equatorial and polar plasma pressures and $B_0$ is the dipole field strength at the base of the corona. Reasonable choices of these physical quantities give a value for this parameter of about 1/2, implying deviations in the large-scale coronal magnetic field geometry from the commonly used potential field that are not negligible. These deviations lead to field lines that are more nearly vertical at the base of the corona and to more magnetic flux on open field lines than in potential field models with the same magnetic boundary conditions.
J. Geophys. Res., Blue, Paper 1A1119

*AGU membership application continued from preceding page*





7720 Electromagnetic radiation
OBSERVATIONAL EXPERIENCE AND MODEL DATA ON SOLAR EUV, FROM MEASUREMENTS ON AE-E
H.E. Hinteregger (Air Force Geophysics Laboratory Hanscom AFB, Massachusetts 01731), K. Fukui and B.R. Gilson
Information on solar irradiance at wavelengths below 185 nm, observed by the EUVS experiment on the AE-E satellite over the entire development of the present sunspot cycle 21, is important to many investigations of planetary thermosphere and ionosphere. Strictly observational information is presently lacking in both the completeness and the spectral detail required by the more advanced study programs. Therefore, it has been necessary also to develop computer models in connection with fully detailed compilations of an appropriate reference spectrum. Our adoption of appropriate forms of effective publication has been difficult for various reasons. Recognizing that full reproduction of our various lists of observational, reference, and model data in scientific journals would be impracticable, we started a more or less informal procedure of timely release of information to a limited number of particularly interested colleagues. With the present letter, we hope to mitigate at least some of the dissatisfactory aspects of this procedure. (EUV, reference spectrum, models).
Geophys. Res. Lett., Paper 1L1323

7725 Flares (Neon Composition)
NEON COMPOSITION IN SOLAR FLARES
T.R.Venkatesan, C.M.Nautiyal, and M.N.Rao (Physical Research Laboratory Ahmedabad INDIA).
Based on the study of implanted solar flare particles in the lunar feldspars, the long term neon composition of solar flares has been inferred to be close to 'solar' rather than 'planetary'. Selective chemical etching followed by stepwise mass spectrometric analyses indicated absence of any 'planetary' component in those samples. The experiment revealed that the implanted solar flare neon had a high Ne-20/Ne-22 value (≈12.0) which is quite distinct from the value for solar flares as determined by spacecraft measurements as well as from that for the 'planetary' neon (≈8.0). Besides, the elemental abundances of noble gases as inferred from lunar minerals and spacecraft measurements is shown to be in agreement with solar abundances and not with the 'planetary' abundances. (Solar flare neon, lunar soil, noble gas, planetary composition).
Geophys. Res. Lett., Paper 1L1407

7770 Sunspots
DEVELOPING FORECASTING CHARTS FOR SUNSPOT NUMBERS
S. G. Kapoor (Department of Mechanical and Industrial Engineering, University of Illinois, Urbana, IL 61801) and S. M. Wu.
A new statistical modeling approach is used to fit models to 200 years of sunspot data and the adequate models for yearly, monthly and daily sunspot numbers are employed to obtain the minimum mean squared error forecasts. The analysis of new models revealed a long term 76-year period, a short term 27-period and a 2.5-year period due to stratospheric winds in addition to a commonly known 11-year periodicity of the sunspots. The forecasting charts are developed in a format that can be easily read to obtain the long term (yearly average) and short term (daily average) predictions of sunspot numbers.
J. Geophys. Res., Blue, Paper 1A1421

# Tectonophysics

8130 Heat flow
THERMAL AND TECTONIC IMPLICATIONS OF HEAT FLOW IN THE EASTERN SNAKE RIVER PLAIN, IDAHO
C. A. Brott, D. D. Blackwell (Dept. of Geological Sciences, Southern Methodist University, Dallas, TX 75275), and J. P. Zitngos
Data from 248 holes in the eastern Snake River Plain show high heat flow values along the margins and low heat flow values along the center because of effects of the extensive Snake Plain aquifer. Based on a thermal model of the aquifer, a heat budget was derived from which a mean heat flow for the eastern Snake River Plain of 190 mWm$^{-2}$ was calculated. This value can be compared to observed values along the margins of 120 mWm$^{-2}$ and two values below the aquifer in deep holes along the northeastern margin of 110 and 109 mWm$^{-2}$. The area of highest expected values, the Island Park caldera, has not been sampled by heat flow measurements, however. A finite-width moving-source-plane thermal model is developed for the regional heat flow of the Snake River Plain. Even though the geological and geophysical characteristics of the eastern and western parts of the Snake River Plain are somewhat different, they are attributed to the same moving heat source and related to different stages in a time-related sequence of thermally-driven geological and tectonic events. The sequence of events is first emplacement of a thick mafic intrusive in the mid-levels of the crust. Associated with this thermal event are regional uplift of a km or so as the heating occurs, melting of the upper crust, generation of a granitic batholith, and rhyolitic volcanism. Rapid subsidence of ½ to 1 km immediately follows because of the change in density of the crust and upper mantle section associated with the emplacement of the basic intrusive and the disruption of the granitic upper crust. After the heat source moves eastward, continued subsidence occurs due to cooling of the lithosphere section (analogous to cooling oceanic lithosphere). Along with the subsidence and soon after the silicic volcanism, basalts began to be extruded. Thermal contraction also generates faulting on the sides and perhaps in the center of the hot spot track. The subsidence causes reversal of the dips of the silicic ash flows from their initial away-from-the-source configuration, to the toward-the-source configuration observed in the Snake River Plain. Continued subsidence and cooling cause the formation of the basin which is then filled by sediments, causing additional subsidence due to isostatic adjustment (the Western Snake River Basin). Thus the physiographic and volcanologic aspects of the Snake River Plain-Yellowstone Region are consequences of a single thermal event and all stages in the future history of the Yellowstone region and the past history of the Western Snake River Basin are represented by westward or eastward traverses (respectively) along the Snake River Plain. (Heat flow, hot spot, continental lithosphere).
J. Geophys. Res., Red, Paper 1B1245

8150 Plate tectonics
CAUSES AND CONSEQUENCES OF THE RELATION BETWEEN AREA AND AGE OF THE OCEAN FLOOR
B. Parsons (Department of Earth and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, Mass. 02139)
The distribution of area of the ocean floor with age, t, is approximately described by

$$\frac{dA}{dt} = C_0\left(1 - \frac{t}{t_m}\right)$$

where $C_0$ is the rate of crustal generation and $t_m$ the maximum age. A linear differential area versus age relation can be explained by a balance between crustal generation and consumption where consumption is uniformly distributed with age. The present distribution of consumption with age was estimated from the isochron map used to derive the area-age relation and a recently published set of angular velocity vectors describing present plate motions. The rate of consumption per unit age shows considerable scatter about a mean value equal to $C_0/t_m$ (~1.7 × $10^{-8}$km$^2$/yr$^2$), but consumption is sufficiently close to being uniformly distributed with age to explain the observed degree of approximation to a linear differential area-age relation. The trenches appear to be distributed randomly with respect to age provinces in the ocean. It was not possible to discern any trend of mean subduction velocities with age apart from the smaller velocities observed for the two youngest age provinces (0-9 Ma).
Changes in the rate of plate generation and the distribution of consumption with age result in shifts in the area-age distribution. In turn these shifts produce changes in the plate driving forces which act to restore the rate of plate generation and distribution of consumption to their initial states. The ridge pushing force, for example, decreases as the rate of crustal generation increases. This coupling between driving forces and the area-age distribution provides a feedback mechanism limiting the extent of any changes. A measure of the magnitude of shifts in the area-age distribution is given by global changes in sea level. If long-term changes in sea level are less than 150m as suggested by recent estimates then only small changes (~12%) in the rate of plate generation and distribution of consumption with age are required. Sea level changes as large as 300m require about a 50 per cent change in the rate of crustal generation.
The above area-age relation can be combined with simple expressions for depth and heat flow versus age to obtain an empirical hypsometric distribution, parameterized in terms of age, and exact expressions for the heat loss from the ocean floor. The latter is estimated to be 2.9 x $10^{13}$W, with 25 per cent of this heat being lost by sea floor younger than 5 Ma. Of the total heat loss from the mantle 26 per cent is estimated to be transported by small-scale convection. (Area-age, sea-level changes, heat flow, driving forces).
J. Geophys. Res., Red, Paper 1B1394



8150 Plate tectonics
THE JUAN DE FUCA RIDGE--HOT SPOT--PROPAGATING RIFT SYSTEM: NEW TECTONIC, GEOCHEMICAL, AND MAGNETIC DATA
John R. Delaney, H. Paul Johnson, and Jill L. Karsten (University of Washington, Department of Oceanography WB-10, Seattle, WA 98195)
Underway geophysics, deep tow camera work, and preliminary geochemical and magnetic studies, from a 1980 cruise to the Juan de Fuca Ridge, allow the following interpretations: (1) the central third (between 45.5°N and 46.5°N) of the ridge is now actively spreading from a zone which is 10 to 20 km west of the axis bisecting the Brunhes-Matuyama magnetic reversal boundary, (2) the apparent terminus of surficial igneous activity at the northern tip of the active 'Cobb Propagator' has been identified by dredging and camera work; the tip appears curved, or offset slightly, to the east, does not correspond to the northernmost tip of the central magnetic anomaly (Elvers et al., 1974), and spreading has been initiated beneath volcanics farther north, and (3) iron and titanium in fresh glasses from the active volcanic zone exhibit a progressive enrichment northward, then a pronounced reversal to more 'normal' concentrations in the vicinity of the Cobb Offset.
J. Geophys. Res., Red, Paper 1B1390

8180 Structure of the Lithosphere
RECONSTRUCTED SEISMIC VELOCITY STRUCTURE OF THE LEWIS HILLS MASSIF AND IMPLICATIONS FOR OCEANIC FRACTURE ZONES
J. A. Karson (Woods Hole Oceanographic Institution, Woods Hole, MA 02543)
The Lewis Hills Massif of the Bay of Islands Ophiolite Complex provides a lower crustal to upper mantle cross-section of an oceanic fracture zone segment and adjacent oceanic lithosphere. The structural and petrologic character of the fracture zone region is distinctly different from the comparatively simple layered structure of the rest of the Bay of Islands Complex. Results of detailed field mapping, petrography, and laboratory seismic velocity measurements have been combined in order to reconstruct the seismic velocity structure of this slice of oceanic lithosphere. Velocities and velocity anisotropies of each of the major rock units in the massif are restored to their preobduction geometries relative to different stratigraphic levels in the complex and proximity to the fracture zone complex.
Although all oceanic fracture zones probably have unique structural and petrologic characteristics in detail, from the perspective of the present study it is suggested that, in general, seismic properties differing from that of 'normal' oceanic crust and upper mantle may be expected within approximately 10km of the axis of fracture zones. In these regions lower crustal as well as upper mantle anisotropy is expected. The Moho might be expected to shallow, due to the presence of abundant ultramafic cumulates, resulting in crustal thinning, and significant velocity inversions may occur with depth where large cyclic mafic layers occur within cumulate ultramafics. In oceanic lithosphere which has passed or is passing through a transform fault domain, enhanced mantle anisotropy might occur. The middle to lower crust in these regions should be comprised of highly anisotropic cataclastic rocks which grade upward into serpentinites and highly fractured gabbros, diabases, and basalts with relatively low velocities. It is suggested that velocities as well as velocity anisotropies produced by these types of structures might be determined in situ by seismic refraction experiments and may be used to map the extent of deformation in the oceanic lithosphere near fracture zones. (Ophiolites, fracture zones, seismic velocities)
J. Geophys. Res., Red, Paper 1B1589

8199 Tectonophysics - miscellaneous
STRUCTURAL FABRIC OF THE PALEOZOIC GOLCONDA ALLOCHTHON, ANTLER PEAK QUADRANGLE, NEVADA: PROGRESSIVE DEFORMATION OF AN OCEANIC SEDIMENTARY ASSEMBLAGE
E.L. Miller (Department of Geology, Stanford University, Stanford, California 94305, USA) L.R. Kanter, D.K. Larue, and R.J. Turner, and B. Murchey (U.S. Geological Survey, Menlo Park, California 94025, USA) and D.L. Jones
The Golconda allochthon in Nevada consists of structurally complex mid- to late Paleozoic basinal sedimentary and volcanic rocks deformed under low temperature and pressure conditions and emplaced onto the North American shelf in the Permo-Triassic. Above the basal thrust in the Antler Peak area, the allochthon consists (in ascending structural order) of late Early to early Late Permian thick bedded chert ("Pumpernickel subunit 1"); Pennsylvanian and Early Permian thin bedded chert, argillite and siltstone ("Pumpernickel subunit 2"); Mississippian siliciclastic turbidites ("Jory unit") and undated chert and argillite of the "Trenton unit."
Open to tight folds in subunit 1 trend north-south and are east-vergent. Folds in thinner bedded subunit 2 vary considerably in style. Fold axes in this unit are distributed within the mean axial plane (oriented N-S, 60°W) but exhibit a west-northwest trending data gap. Boudin axes measured in zones of highly disrupted layering (interpreted as zones of movement or shear) exhibit similar patterns without data gaps. These girdled distributions in part reflect rotation of these elements upon greater strain towards the east-west trending direction of tectonic transport or towards parallelism with the X-axis of the strain ellipsoid. Assymetry of folds indicate movement was west to east. Locally developed late stage folds in subunit 2 are subhorizontal, trend north-south, and are compatible with fold-fault solutions that indicate east-directed thrusting. Striations measured within fault zones yield bidirectional east-west slip lines.
Our fold and fault data indicate that east-west shortening of these basinal sediments was accomplished by folding and east-directed thrust faulting during a single progressive deformational event. This conclusion is supported by the presence of a major west-dipping thrust fault in the map area that places Mississippian over Permian rocks. The allochthon formed as an east-vergent submarine fold and thrust belt that was subsequently thrust on the continental shelf. Autochthonous rocks beneath the Golconda thrust are virtually undeformed, suggesting that most of the structure in the allochthon formed prior to its ultimate emplacement. (structural analysis, Golconda allochthon).
J. Geophys. Res., Red, Paper 1B1426

8199 General
GRAVITY-INDUCED STRESSES NEAR TOPOGRAPHY OF SMALL SLOPE
David F. McTigue (Department of Earth and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, MA 02139) Chiang C. Mei (Department of Civil Engineering)
Topographic modification of gravity-induced near-surface stresses results in significant departures from a lithostatic state. A perturbation scheme provides approximate analytical solutions for plane strain of an elastic half-space with an irregularly shaped free surface of small characteristic slope, ε. The leading order effect of the topography is equivalent to that of a distributed normal load on a plane boundary, and the correction at order ε is due to a distributed shear traction on a plane boundary. In the near-surface region, these two effects contribute at the same order to departures from the lithostatic stress field. [illegible]
J. Geophys. Res., Red, Paper 1B0899

# Volcanology

8699 Volcanology topics
THE ICELAND RESEARCH DRILLING PROJECT IN RELATION TO THE GEOLOGY OF ICELAND
I.B. Fridleifsson (National Energy Authority, Grensasvegur 9, 108 Reykjavik, Iceland)
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J. Geophys. Res., Red, Paper 1B1970

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GEOMETRY AND PHYSICAL PROPERTIES OF THE SOCORRO, NEW MEXICO, MAGMA BODY
Thomas M. Brocher (Department of Geological and Geophysical Sciences, Princeton University, Princeton, New Jersey 08544; now at the Hawaii Institute of Geophysics, University of Hawaii, Honolulu, Hawaii 96822)
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J. Geophys. Res., Red, Paper 1B1267

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AIRCRAFT SAMPLING OF THE SULFATE LAYER NEAR THE TROPOPAUSE FOLLOWING THE ERUPTION OF MOUNT ST. HELENS
Erwin A. Lezberg (National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio) [illegible]
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J. Geophys. Res., Green, Paper 1C1476

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P. T. Robinson (Department of Geology, Dalhousie University, Halifax, Nova Scotia, Canada) [illegible]
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J. Geophys. Res., Green, Paper 1C1167

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THE MT. HOOD REGION: VOLCANIC HISTORY, STRUCTURE, AND GEOTHERMAL ENERGY POTENTIAL
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GRAVITY AND THERMAL MODELS FOR THE TWIN PEAKS SILICIC VOLCANIC CENTER, SOUTHWESTERN UTAH
Daniel L. Carrier and David S. Chapman (Department of Geology and Geophysics, University of Utah, Salt Lake City, UT 84112)
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Chronicles



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